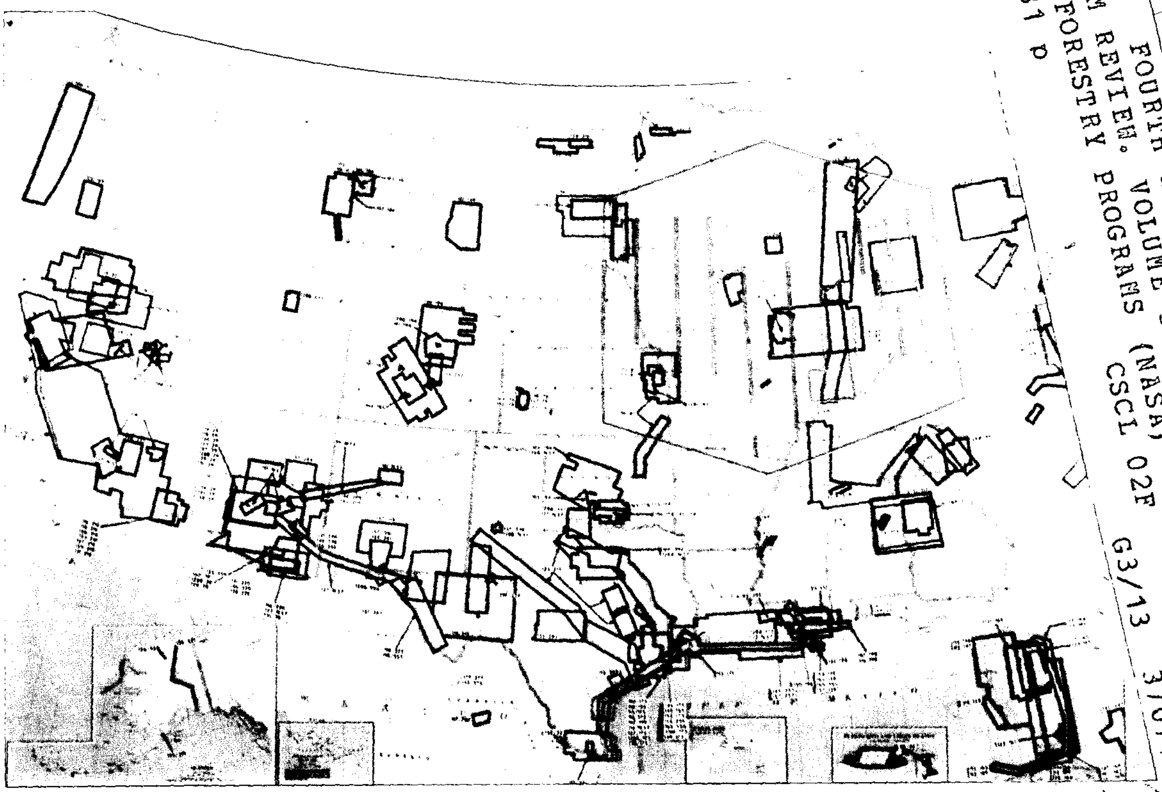
MSC - 05937

# 4th ANNUAL EARTH RESOURCES PROGRAM REVIEW

## VOLUME V
## AGRICULTURE AND FORESTRY PROGRAMS





Presented at the
Manned Spacecraft Center
Houston, Texas

January 17 to 21, 1972

PRECEDING PAGE BLANK NOT FILMED



## FOREWORD

A review of various aspects of the Earth Resources Program was held at the Manned Spacecraft Center, Houston, Texas, January 17 to 21, 1972. Particular emphasis was placed on the results of analysis of data obtained with the Manned Spacecraft Center and other aircraft which have contributed data to the program.

The review was divided into the disciplinary areas of Geology, Geography, Hydrology, Agriculture, Forestry, and Oceanography. Program investigators presented the results of their work in each of these areas. The material presented is published in five volumes:

VOLUME I - NATIONAL AERONAUTICS AND SPACE ADMINISTRATION PROGRAMS - N72-29302

VOLUME II - UNIVERSITY PROGRAMS N72-29327

VOLUME III - U.S. GEOLOGICAL SURVEY PROGRAMS N72-29355

VOLUME IV - NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION PROGRAMS AND U.S. NAVAL RESEARCH LABORATORY PROGRAMS N72-29378

VOLUME V - AGRICULTURE AND FORESTRY PROGRAMS N72-29407

The review provided a current assessment of the program for both management and technical personnel. Note that the material presented represents the current status of ongoing programs and complete technical analyses will be available at a later date.

Where papers were not submitted for publication or were not received in time for printing, abstracts are used.

## FRONT COVER

The map on the front cover depicts the NASA Earth Resources aircraft coverage of the United States through June 1971.

CONTENTS OF VOLUME I

CONTENTS OF VOLUME II

# CONTENTS OF VOLUME III

RC

## CONTENTS OF VOLUME IV

CONTENTS OF VOLUME V

N 72-29408



SECTION 115

# DEVELOPMENT OF ANALYSIS TECHNIQUES FOR REMOTE SENSING OF VEGETATION RESOURCES

By

William C. Draeger
Forestry Remote Sensing Laboratory
University of California
Berkeley, California



## INTRODUCTION

During the past year, the activities of the Forestry Remote Sensing Laboratory have consisted primarily of the development of various data handling and analysis techniques which will be used in our forthcoming evaluations of ERTS-A and supporting high-flight imagery. In general, these evaluations will be concerned with the application of remote sensing to wildland and agricultural vegetation resource inventory problems. The following discussion briefly summarizes several of the more significant developments which will be used in these ERTS investigations.

## MONITORING OF CALIFORNIA'S ANNUAL GRASSLAND

Studies conducted using small scale (1:120,000) RB57 color and color infrared photographs of the annual grassland areas of the state of California have indicated a potential for the development of models which would permit a prediction of regional forage production in the annual grassland type.

Specifically, sequential synoptic coverage of the area during the fall (between October 1 and November 30) and the spring (mid-February to mid-May) should allow an estimate of the time of seed germination and the time of "near-peak foliage development". The time of seed germination in the fall is monitored by observing when the range, which remains dry all summer, suddenly appears green. The time of peak foliage development can be estimated with reference to that time in the spring when the grassland reaches an "optimum photogenic stage" wherein grasses have dried on shallow soil sites but are still green on deeper soils (see Figures 1 and 2).

Presumably the greatest forage production will occur in those years when the seeds germinate early in the fall, and in which growth continues until late in the spring. Conversely, poorest production will result from late germination and early maturation, both of which are affected by the timing and intensity of rainfall, and temperature fluctuations. In order to actually make quantitative estimates of forage production for specific parts of the state of California, it will be necessary to establish "benchmark" dates of germination and maturation which correspond to minimum, average, and maximum production, and to provide allowance for interaction between germination and maturation dates for the various regions within the annual grassland type. However, preliminary investigations indicate that it should be possible to establish such reference data which can be correlated with those parameters observable on small scale sequential imagery.

Information acquired about the development of the annual grassland crop has many applications. First, one can predict which areas may be over-utilized because crops are below average, or under-utilized because the existing number of cattle cannot possibly consume the above average crop of forage. Thus, information regarding expected crop yield could lead to better utilization of the crop. By predicting the length of the growing period, the rancher is in a more favorable position to know when to move his grazing animals to market to obtain the best price, or to determine how much additional hay he may need for supplemental feeding, if he chooses to keep his cattle on the annual range. Producers of livestock feed could also benefit from this information. Finally, the rancher might also use this information to determine when it is best to move his grazing animals from the annual range to other kinds of pasture.

## AUTOMATIC TEXTURE ANALYSIS

The principal efforts of the automatic data processing unit during the past year have centered around modification and use of routines derived from the LARS (Purdue) facility which are based upon spectral "point cell" classification procedures, in which each data point is analyzed independently. However, our experience in the analysis of imagery of wildland areas has indicated that in many cases, considerable information can be extracted through the use of "textural" analysis as well. Our ultimate objective is that of investigating the means whereby spectral and textural data can be combined to facilitate feature classification procedures. The result is expected to be the achievement of an increased classification accuracy as well as a more flexible classifier routine for non-agricultural terrain features.

In an effort to extract spatial frequency (textural) information, a transform routine has been developed for our terminal/display system. The routine employs a modified one-dimensional Hadamard transform algorithm to derive the textural data. The Hadamard transform was chosen in this instance because of its relatively low computational cost, and its ease of adaptation to our small computer facility. The program generates a series of "digital masks" of increasing periodicity, and causes these "masks" to shift regularly and sequentially in relation to the scanned image, thus generating a series of energy coefficients. The minimum, maximum, and mean energy coefficients are computed for each scan line and averaged over several scan lines taken from the area of interest.

Preliminary results using this procedure have shown significant correlations between the energy coefficients of scanned images of timber stands and ground measurements of timber volume (r = 0.97) and basal area (r = 0.95) of the same stands. Thus, it appears likely that we will be able to develop useful "textural signature" responses through the automatic scanning of imagery which has been manually typed into homogeneous units which will yield estimates of parameters of interest to forest land managers (see Figures 3 and 4).

## AGRICULTURAL GROUND DATA COLLECTION TECHNIQUES

In the interest of developing more efficient methods of collecting "ground" data to support our analyses of small scale imagery for conducting agricultural inventories, an experiment was carried out in Maricopa County, Arizona, wherein the use of ground crews was compared with helicopters and fixed-wing aricraft. Ten permanent "ground truth" cells, each four-square-miles in size were visited using each of the three methods, and a field-by-field crop identification was performed. Subsequently, identification accuracy, and time and cost comparisons were made of the three methods. Conventional rental rates for aircraft, helicopters, and automobiles were used in the comparison.

It was assumed that the ground inventory was 100 percent correct. Both the helicopter and the fixed-wing aircraft methods averaged 2 to 3 percent error based on number of fields. It was felt, however, that most of the errors were of the sort that could be corrected on the next monthly inventory as the crops matured, since the bulk of the errors were on young cereal grain crops which would soon become readily identifiable.

In terms of time and costs extrapolated from the ten test cells to the total of 32 four-square-mile cells in the county, it was estimated that a complete data acquisition operation would cost approximately $2200 using the helicopter, $700 with fixed-wing aircraft, and $1000 by automobile. The time of actual data collection for both helicopter and fixed-wing aircraft were about the same (and approximately five times faster than with automobiles), however, the per hour rental cost of helicopter (with pilot) is nearly five times greater than that of conventional aircraft, thus accounting for the wide disparity in overall cost of the two methods (see Figure 5).

It is planned that further studies of the relative efficiency of aircraft and ground methods will be carried out during the current growing season.

## SPECTRAL MEASUREMENTS

During the past year a spectral data gathering capability has been developed which allows in situ measurements of the spectral reflectance of vegetation and terrain features to be gathered in conjunction with measurement of the spectral distribution of incident illumination. The acquisition of both of these parameters simultaneously makes possible the computation of standardized reflectance data, thus permitting valid comparisons of data gathered at different times, or under different atmospheric conditions. The equipment consists of a battery of two EG&G spectroradiometers which measure reflected radiation from 350 nanometers to 1200 nanometers in wavelength, and an ISCO spectroradiometer which records incident illumination over the same wavelength range. The data from both instruments is recorded on magnetic tape, which facilitates computer computation of standardized data. The system is essentially field-portable, which is necessary considering the impossibility of obtaining meaningful reflectance data of natural vegetation and terrain features if they must be transported to the laboratory (see Figures 6, 7 and 8).

During the past year several studies have been carried out using this data-acquisition equipment. At the Harvey Valley test site, over one hundred readings were made of five major plant species. This data has been used to define optimum film-filter specifications for large scale photography of the site used in a range inventory experiment. In Maricopa County, Arizona, a project was initiated to assess the feasibility of using the equipment from a helicopter in order to integrate reflected radiation from larger ground areas than is possible from the ground. The field of view from the helicopter (250 feet in diameter at an altitude of 1000 feet) approximates the resolution expected from ERTS-A. The results were promising, and further studies of this type are planned in conjunction with the flight of ERTS-A and the supporting high-flight imagery. In addition, during the next

2V

field season, studies will be conducted to determine the feasibility of utilizing large homogeneous natural features for calibration of high-flight imagery. This is necessary to insure repeatability of results when such imagery is viewed using additive color-enhancement devices for discrimination and identification of vegetation features in both wildland and agricultural areas.

## CONCLUSIONS

While none of the techniques discussed here have been carried out to their final conclusion, it is felt, as was stated earlier, that in each case they provide a means by which the forthcoming analysis of ERTS imagery can be more efficiently conducted. Thus the past year has been viewed as one in which a state of readiness has been achieved in anticipation of the extensive experiments which are scheduled for the next several years.

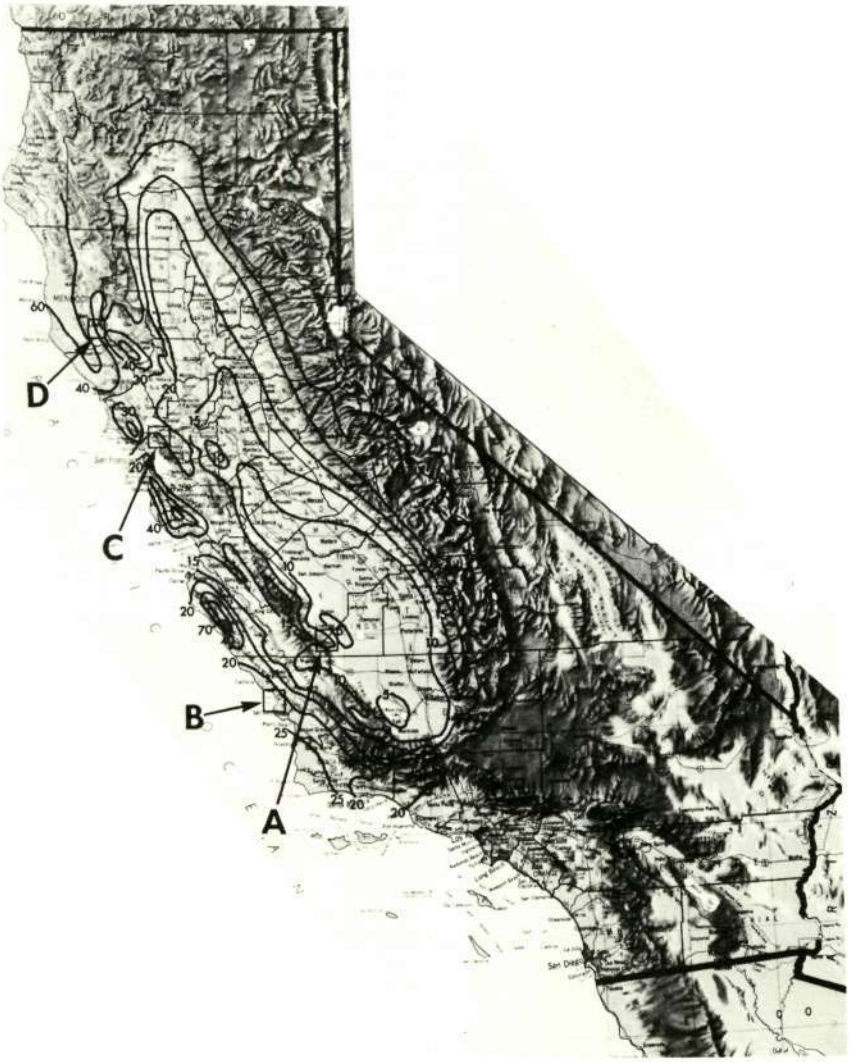



Figure 1.- The four test sites which appear in Figure 2 are indicated on this map of California. Average annual rainfall is 8" at area A, 22" at area B, 20" at area C, and 40" at area D. All of these sites are within the range of the California annual grassland type.

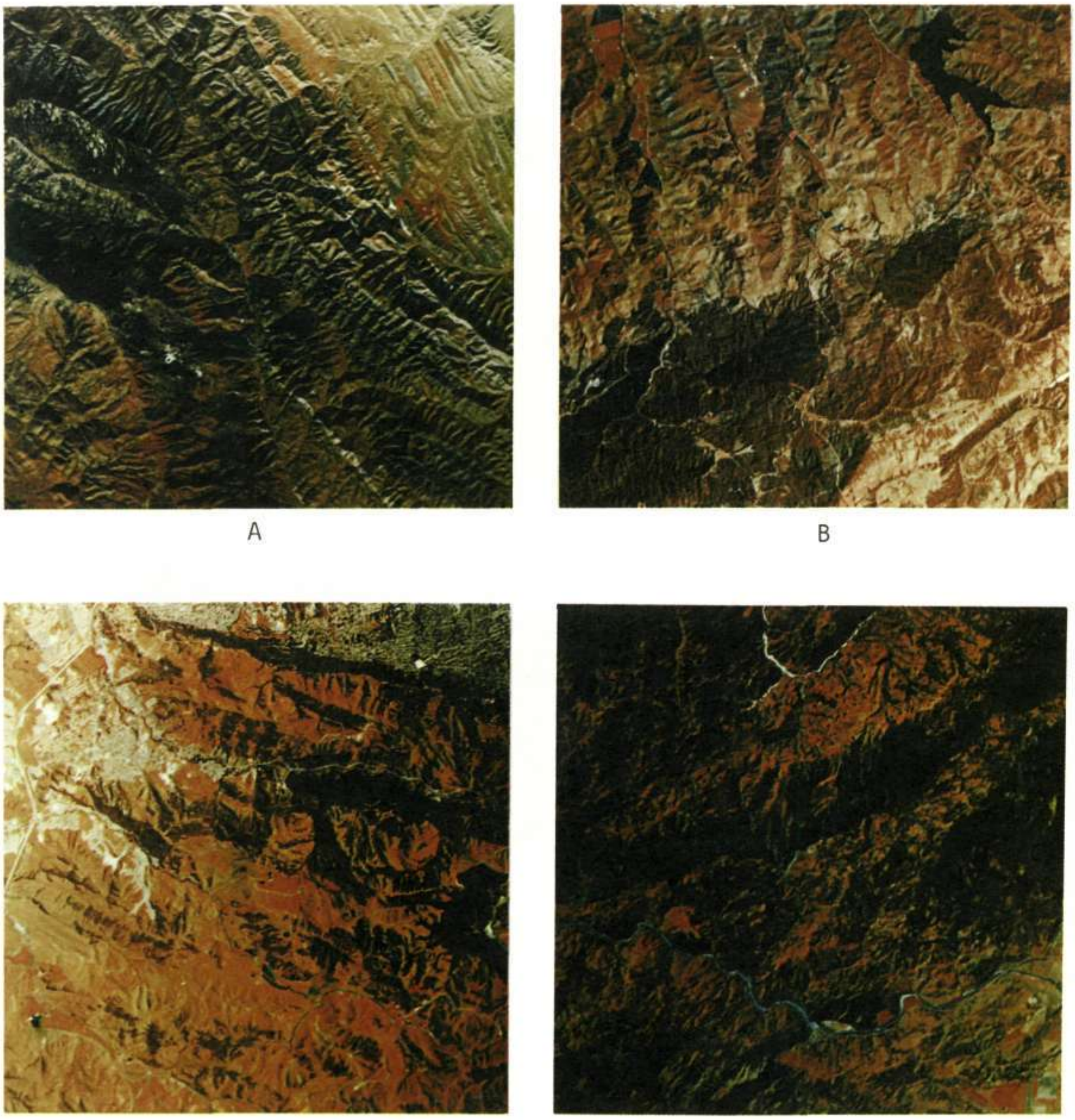



Figure 2.- These color infrared photos (scale = 1:120,000) of four annual grassland test sites were taken on April 1, 1971. At this early date the grasses at sites A and B have already reached their "optimum photogenic stage", indicating a below average forage crop, while at areas C and D the grasses are not yet mature, indicating a probable average or above-average production year for those sites.

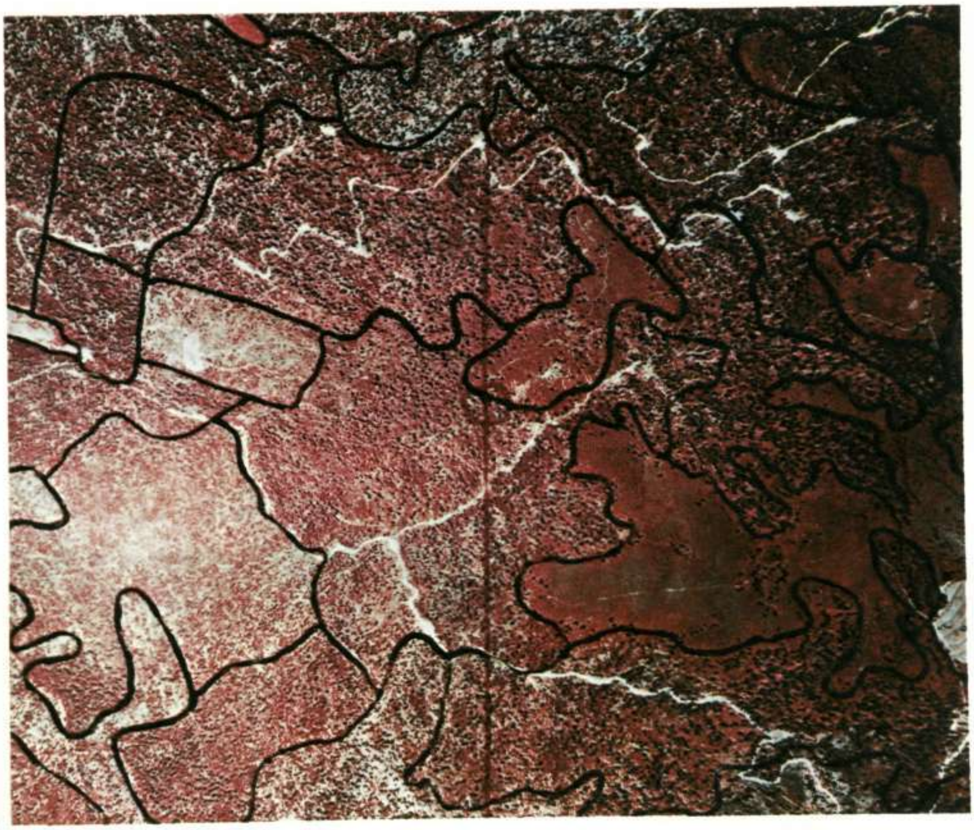


Figure 3.- This color infrared photo, scale 1:25,000 was delineated on the basis of timber size and density, and textural data for each type was extracted using a scanning densitometer and mathematical transform routines (see text for discussion). It was hoped that such textural data would be useful in estimating various timber stand parameters of interest to the wildland manager. Some results of this study are illustrated in Figure 4.

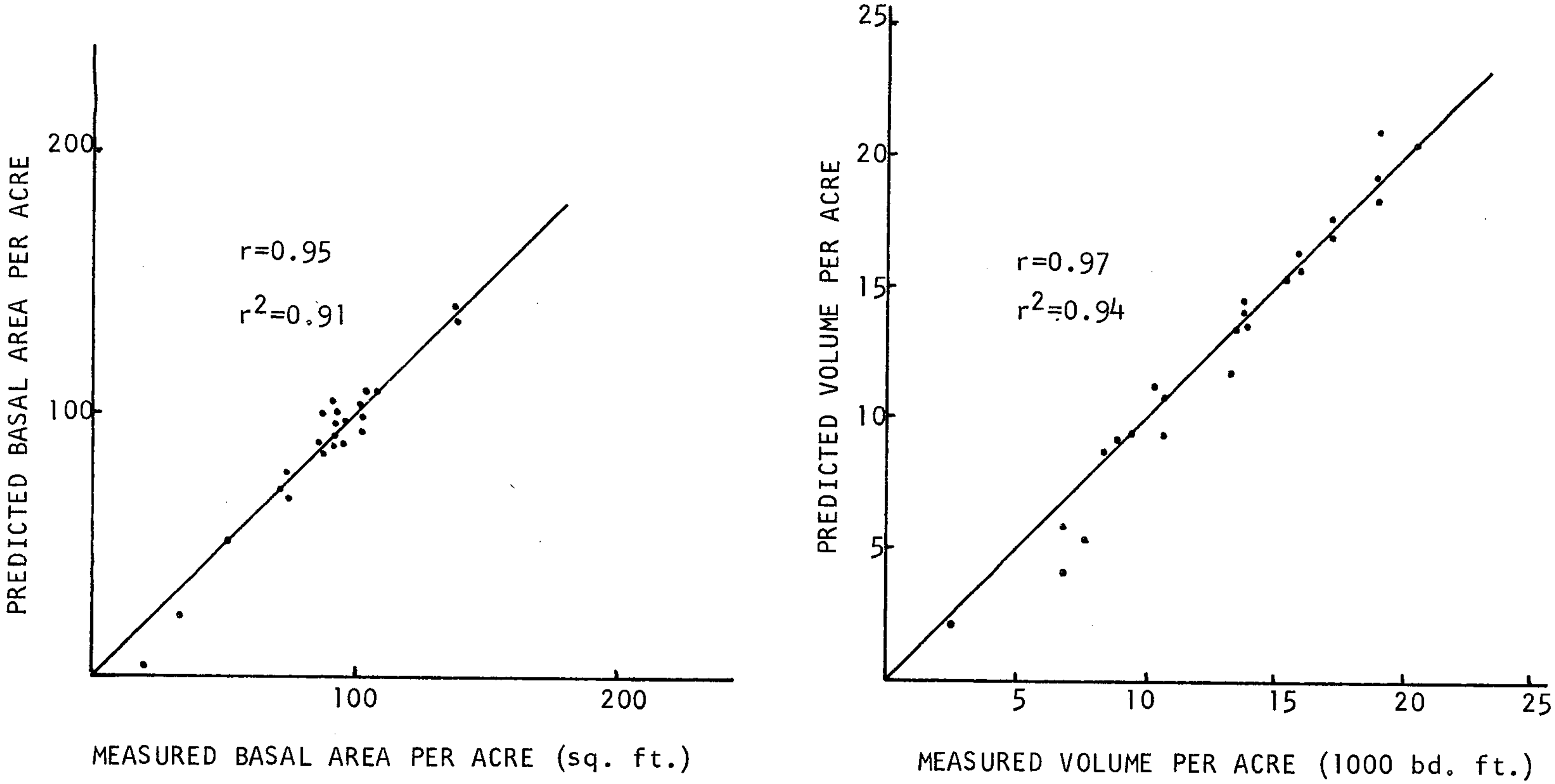



Figure 4.- These two graphs illustrate the high correlation between textural information pertaining to timber stands, such as those shown in Figure 3, and stand parameters, such as timber volume per acre and basal area per acre. In both examples, the "predicted" values were derived using textural data extracted from aerial photographs.

COMPARISON OF

DATA COLLECTION METHODS

| | Automobile | Helicopter | Airplane |
|---|---|---|---|
| Average Error | 0 | 3.2 | 2.2 |
| Time of Data Collection ( 32 4 sq. mi. plots) | 72 hrs. | 13 hrs. | 13 hrs. |
| Estimated Total Cost | $990 | $2266 | $706 |

Figure 5.- This table indicates the differences in accuracy and cost of three methods of acquiring "ground truth" information about agricultural crops to support image interpretation investigations. The data were gathered at the Maricopa County, Arizona test site. The error is expressed in percent based on number of fields, while the total cost is estimated on the basis of acquiring crop type information for all fields within the 32 permanent sample plots within the test area.

Figure 6.- The Forestry Remote Sensing Lab spectral measurements equipment consists of two EG&G spectroradiometers (above) for measuring in situ reflectance of natural features, and an ISCO spectroradiometer (right) for gathering simultaneous incident illumination data.

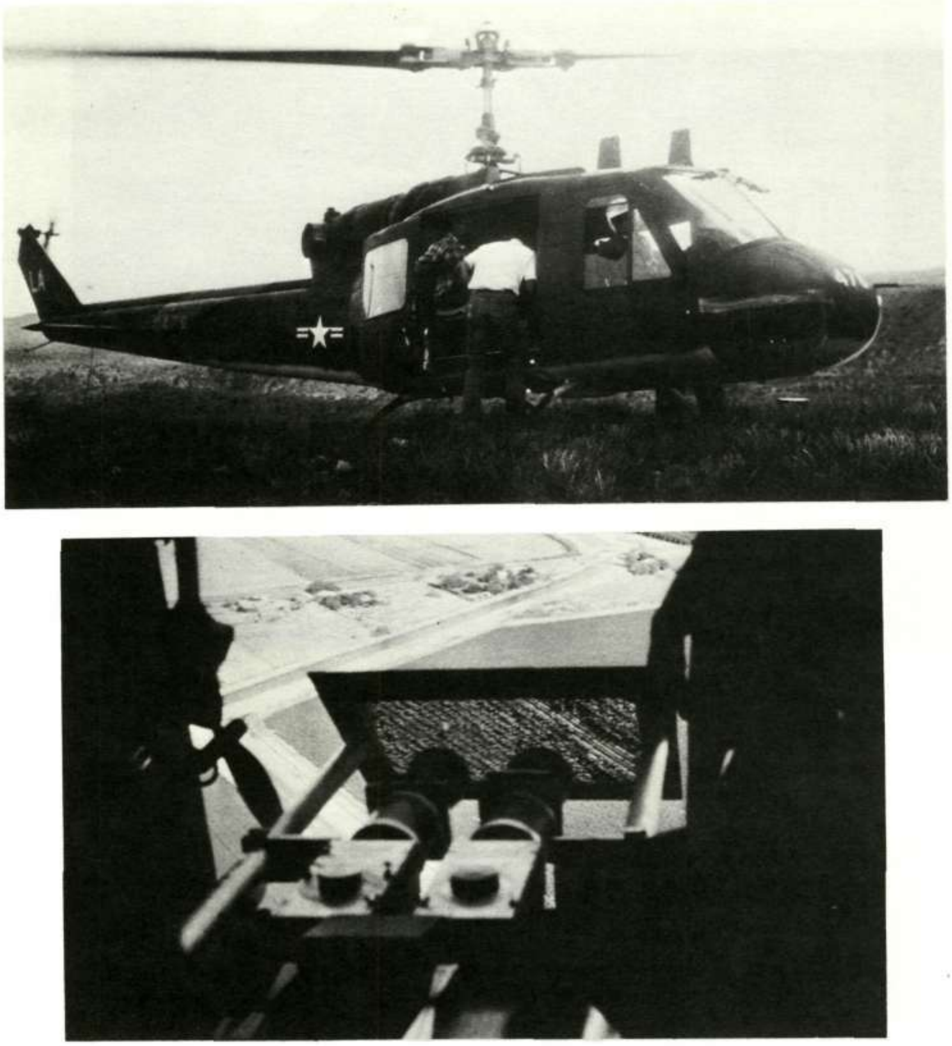


Figure 7.- In order to gather spectral reflectance data of large integrated areas such as will comprise a resolution element of ERTS imagery, measurements of agricultural and rangeland areas have been taken from a helicopter. The bottom photo shows a cotton field as seen from the helicopter with the two EG&G radiometers in operation. Using this equipment, from an altitude of 1000 feet the field of view is roughly 250 feet in diameter, approximating the resolution expected from ERTS-A.

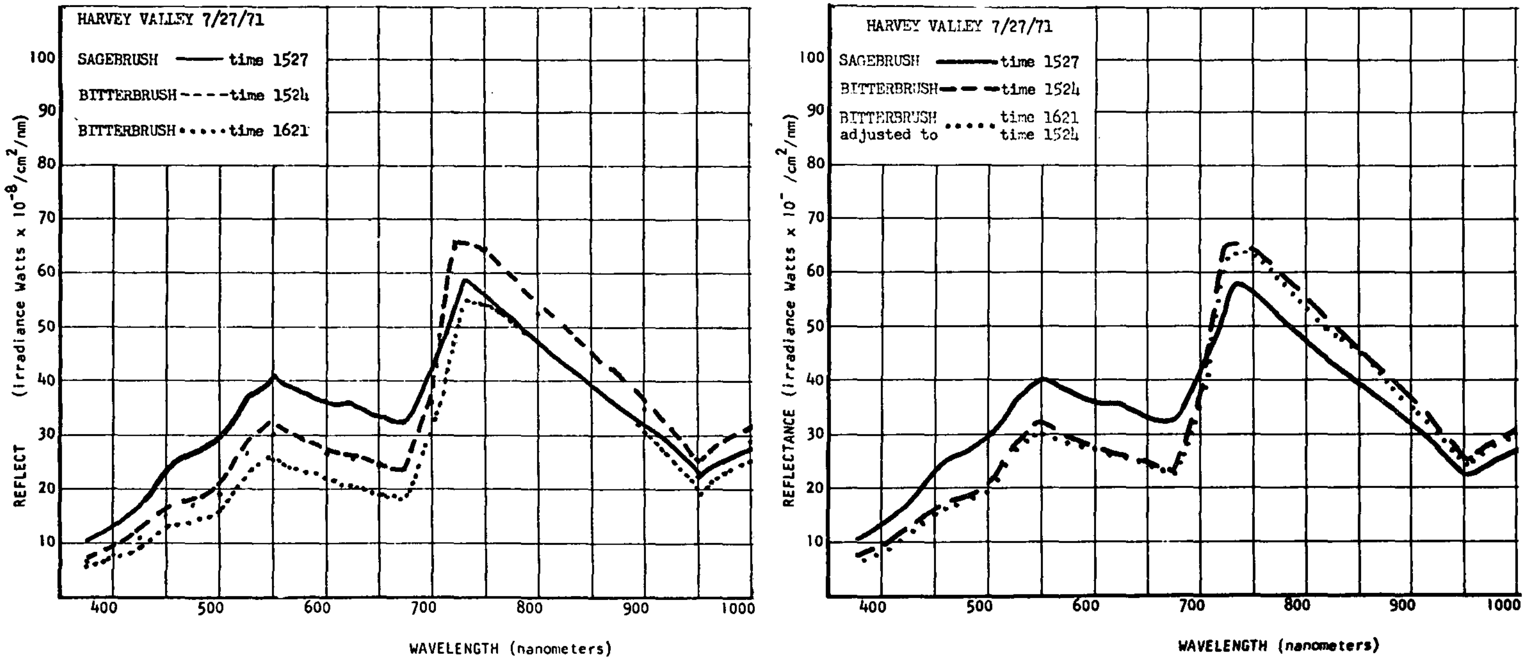



Figure 8.- These graphs illustrate the value of incident illumination data in standardizing in situ reflectance measurements. Note that on the left, reflectance of the same bitterbrush plant taken at different times appears quite different, whereas on the right, where the two readings have been adjusted to a common time, they appear nearly identical. This makes possible a direct comparison of readings taken at different times or under different atmospheric or lighting conditions.

N72-29409



SECTION 116

# RESOURCE ANALYSIS AND LAND USE PLANNING WITH SPACE AND HIGH ALTITUDE PHOTOGRAPHY

by

Barry J. Schrumpf[1]
Range Management Program
Oregon State University
Corvallis, Oregon

The philosophies and concepts upon which this research has been predicated have been clarified in earlier reports to the Earth Resources Program Review by personnel of the Range Management Program, Oregon State University. We have proceeded with the conviction that "remote sensing data have limited value until someone uses the information to make a decision or to facilitate action that benefits man" (Poulton, Faulkner, and Schrumpf, 1970); and with this basic concept: "In naturally vegetated areas the discrete, homogeneous plant communities that occupy the landscape are the best indicators of areas of analogous, effective environment--thus, of ecological site and of equivalent potential" (Poulton, Faulkner, and Martin, 1971). Suggestions have been presented for appropriate photographic scales required to provide resource data for the decision-making processes of land use planning and management (Poulton, Driscoll, and Schrumpf, 1969). A legend system for barren lands, water resources, natural vegetation, agricultural, urban, and industrial lands constructed in a hierarchical framework was introduced, accompanied by a mapping symbol format (Poulton, Faulkner, and Schrumpf, 1970).

The current report deals with the application of these ideas and developments in the production of two natural vegetation resource and land use maps for a major portion of Maricopa County, Arizona; both maps are photo maps. Maricopa County is 9,238 square miles in size. One photo map displays an inventory of approximately 90% of that area, depicting eleven natural vegetation types, areas of intensive agricultural and urban land use, and a macrorelief classification of the landscape. It is constructed from portions of 8x8 inch enlargements of

---

[1]In addition to the author, substantial contributions to the work reported here have been made by David P. Faulkner, James R. Johnson, David A. Mouat, and Charles E. Poulton. They are all personnel of the Range Management Program, Oregon State University.

color infrared frames AS9-26-3800 through -3802 (SO-65 Multispectral Photographic Experiment) and presented in Poulton, Johnson, and Mouat (1970). The mosaic for the other photo map consists of seventy black and white copies of high altitude RC-8 Ektachrome photography flown at an original scale of 1:124,000 (NASA Mission 139, July 28, 1970). The working copies of this map are 1:133,000 (Pettinger, L. R., et al, 1970). Approximately 64% of the county is included on this map. Twenty-two vegetation taxonomic units are noted on the map, plus barren lands, water resources, classes of agricultural crops and associated activities, kinds of urban and industrial lands, macrorelief and landform. Of the area imaged, naturally vegetated lands constitute 80%; agricultural lands, 14%; urban areas, 5%; and barren lands and water resources, less than 1%. Each map was produced by first inspecting the photography and grouping images on the basis of macrorelief, color, and pattern characteristics. Ground samples were then obtained representing each class of photographic image. Ground subject-photographic image relationships were determined, and then the remainder of the photography photo interpreted. The locations of ground checking activities and aerial reconnaissance flights are shown in Figure 1. Table I provides a summary comparison of the information content that was portrayed on the two maps. There is an obvious increase in the number of subjects that could be delineated and annotated on the high altitude photo map as compared to the space photo map. This is a result of the increase in interpretive detail and the larger scale available with the larger scale of photography. When comparing the attributes of the two kinds of photography, it can be readily appreciated that the resolution characteristic of space photography imposes limitations on the degree to which identifications can be refined. Furthermore, the photographic scale places limitations on the number of subject representatives that can be delineated and noted on the map, even if they can be properly identified, because of the small size of the photographic images that represent the subjects. A comparison of these two mapping jobs could easily be pushed too far; the purpose of presenting Table I is to give one comparative example of mapping capabilities with the two kinds of photography. Table I does not indicate that high altitude photography is "better" than space photography for mapping purposes. This judgment can only be made in light of the information need that is to be served and the time, money, equipment, and manpower available for satisfying that need.

From Figure 1 it can be seen that approximately 25% of the area represented on the high altitude photo map received intensive ground checking. The remainder of the map was based on photo interpretation. To determine the reliability of the portions of the map produced through photo interpretation an accuracy check was planned and carried out. Sample points located by the intersections of a grid placed randomly over the map were chosen so as to sample delineated subjects in proportion to the total areal amount each contributed to the photo interpreted portion of the map. In ten hours of helicopter[2] flying time, 145 sample points were visited. The areas which include these points are shown in Figure 1. The most distal locations were over one hundred miles apart and several were in very rugged terrain. To accomplish the accuracy check job from the ground would have required many man-weeks. Helicopter navigation was accomplished by visually comparing the high altitude photography (1:124,000) to the terrain while in flight. The locations were found without great difficulty, even in rugged areas. As the helicopter hovered or circled over the sample location, a plant species list with accompanying prominance ratings was recorded. Back in the lab each list was keyed out in the vegetation legend for identification as to taxonomic type. Each accuracy check identification was then compared to the photo map and a tally kept of the correct and incorrect photo interpretations represented on the map. This provided the information given in Table II. A careful study of this Table will yield the following kinds of information.

1) The accuracy with which representatives of specific subjects have been identified. Example: Seventeen of the accuracy check locations supported 321.11 vegetation and they were all identified correctly through photo interpretation giving 100% accuracy (100% - % Error of Omission).

2) The reliability of the photo interpretation identifications for each subject. Example: Thirty-nine accuracy check locations had been determined through photo interpretation as having 321.11 vegetation; of these only seventeen actually did. Therefore, 44% of the 321.11 interpretations were correct (100% - % Error of Commission).

3) A revealing of the kinds of photo interpretation errors that were made. Example: Within the actual 321.2 vegetation group there are three closely related subgroups (321.21, .22, and .23). Photo interpretation errors of the 321.2 group consisted primarily of confusing representatives of the three subgroups. Very few 321.2 representatives were photo interpreted as something outside this group and very few representatives from other than the 321.2 group were mis-identified as 321.2 types.

---

[2]A helicopter and pilots were provided by the U.S. Air Force. Arrangements were made by Robert Miller, U.S.D.A. Remote Sensing Technical Coordinator. Lt. Col. James A. Hamilton, Luke A.F.B. and helicopter crews under his command provided the necessary support.

RE

4) An indication of the consistency with which specific errors were made. Example: All 321.15 representatives were photo interpreted as being 321.11 types (the same error was made 100% of the time).

5) A basis for adjusting for errors. Example: 33% of the 321.11 photo interpretation identifications were actually 321.15 types. Therefore, a table showing the amount of 321.11 and 321.15 types present, as determined through photo interpretation, could be adjusted accordingly (33% of the number of 321.11 types tallied would be removed to the 321.15 tally).

In addition to the above kinds of analyses, the accuracy check data may provide evidence suggesting subjects that were not classified during legend development, or the data may indicate a need for revising some classification criteria.

Table III gives an evaluation of the severity of the kinds of photo interpretation errors that were made. Each kind of error was determined through an analysis similar to that given in (3) above. Sixty-five percent of the interpretations were correct; another 28% involved errors that were inconsequential for some purposes.

A vegetation resources, agricultural and urban land use map, while presenting a considerable amount of information about current surface features and activities, certainly need not be considered an end in itself. One potentially very important use of the information contained in such a map is in land use planning. A brief example follows:

Based on characteristics of specific vegetation types and macro-relief classes, and on observations of past and present land use patterns and conversions occurring in the study area, it was possible to establish criteria for classifying land which was potentially suited for agricultural and/or urban development. Area calculations of lands so suited revealed the following. Approximately 1900 square miles of potential agricultural lands exist yet undeveloped. They comprise nearly 86% of the naturally vegetated flat lands in the inventoried area. Urban lands could also potentially come to occupy the flat lands (with the exception of flood plains) in addition to undulating to rolling lands. Potential urban lands include 90% of the total available naturally vegetated flat lands. Obviously, then, a potential conflict exists which must be addressed as expansion in the area continues. While only 10% of the potential agricultural lands are not in conflict with urban expansion (those lands on flood plains), nearly 35% of those lands suited for urbanization are not suited for agricultural development. If agriculture is to remain as a major component in the land use scene of this region, then zoning and taxes will have to be so structured as to eliminate the potential land use conflict.

Overlays can be constructed to show the areas satisfying the potential land use criteria. Separate overlays were constructed to show both potential agricultural and urban lands. When one is placed over the other the location of lands subject to a potential conflict, as discussed above, are clearly revealed. When the overlays are placed over the photo map they show potential land uses in relation to current uses.

These displays of information (photo maps and overlays) have been extremely valuable for conveying resource information and analyses of that information to other persons. Additionally, they would appear to provide a powerful tool for generating inputs for making land use planning decisions in a manner that facilitates making those decisions.

## BIBLIOGRAPHY

Pettinger, L. R., et al. 1970. The application of high altitude photography for vegetation resource inventories in southeastern Arizona. Final Report for Earth Observations Division, MSC/NASA. Forestry Remote Sensing Laboratory, University of California, Berkeley. 147 p.

Poulton, C. E., R. S. Driscoll, B. J. Schrumpf. 1969. Range resource inventory from space and supporting aircraft photography. Second Annual Earth Resources Aircraft Program Status Review, Vol II. Sept. 16-18. NASA, MSC, Houston, Texas.

Poulton, C. E., D. P. Faulkner, B. J. Schrumpf. 1970. A vegetational inventory and ecological resource analysis. Third Annual Earth Resources Program Review, Vol II. Dec. 1-3. NASA, MSC, Houston, Texas.

Poulton, C. E., J. R. Johnson, D. A. Mouat. 1970. Inventory of native vegetation and related resources from space photography. Annual Progress Report. Range Management, Oregon State University.

Poulton, C. E., D. P. Faulkner, N. L. Martin. 1971. A procedural manual for resource analysis. Application of ecology and remote sensing in the analysis of range watersheds. Final Report. Agricultural Experiment Station, Oregon State University, Corvallis.

TABLE I.- A COMPARISON OF THE INFORMATION CONTENT PORTRAYED ON THE TWO KINDS OF PHOTO MAPS

| Photo Map Type | Number of Mapped Types Annotated on the Photo Maps | | | | | | | Approximate Number of Delineations |
|---|---|---|---|---|---|---|---|---|
| | Natural Vegetation | Barren Lands | Water Resource | Agriculture | Urban | Macrorelief | Landform | |
| Space Photo Map | 11 | 0 | 0 | 1 | 1 | 7 | 0 | 50 |
| High Altitude Photo Map | 22 | 2 | 1 | 6 | 5 | 8 | 9 | 350 |

TABLE II.- COMPARISON OF ACCURACY CHECK INFORMATION AT 145 LOCATIONS WITH PHOTO INTERPRETATION IDENTIFICATIONS FOR THE SAME LOCATIONS MADE ON HIGH ALTITUDE RC-8 EKTACHROME PHOTOGRAPHY

The numbers (321.11, 321.21, etc.) in the row across the top of the table represent those legend units identified by photo interpretation of high altitude photography and delineated and annotated on the photo mosaic map.

The column at the left indicates those legend units identified from the data gathered at the accuracy check points. Each row of the table begins with one of these legend units and the distribution of the numerals along a row indicate how the representatives of the legend unit were identified by photo interpretation. For example, in the row designated 321.22, seventeen check points had been previously and correctly photo interpreted as 321.22 and four were incorrectly identified as either 321.21 or 321.23. Because these latter four were actually 321.22 units interpreted as another subject they represent "errors of omission."

In the column headed 321.11 the numerals indicate that seventeen 321.11 accuracy check points had been previously interpreted correctly. There were other subjects (321.12, 321,15, 321.17, and 321.21) which had also been identified as 321.11 when they were not. These incorrect identifications are called "errors of commission."

Calculation of percent correct, omission, and commission is demonstrated in the following example. Interpreted units (denoted A) are sampled in the accuracy check (denoted B). A comparison is made between the interpreted units (A) and the accuracy checked units (B).

Correct = A agrees with B
Omission = Area identified in B not included in A
Commission = Area interpreted in A does not agree with B

$$\% \text{ Correct} = \frac{\text{Number of A's that agree with B's} \times 100}{\text{Total number of B's}}$$

$$\% \text{ Omission} = \frac{\text{Number of areas identified in B not included in A} \times 100}{\text{Total number of B's}}$$

$$\% \text{ Commission} = \frac{\text{Number of areas interpreted in A not agreeing with B} \times 100}{\text{Total number of A's}}$$

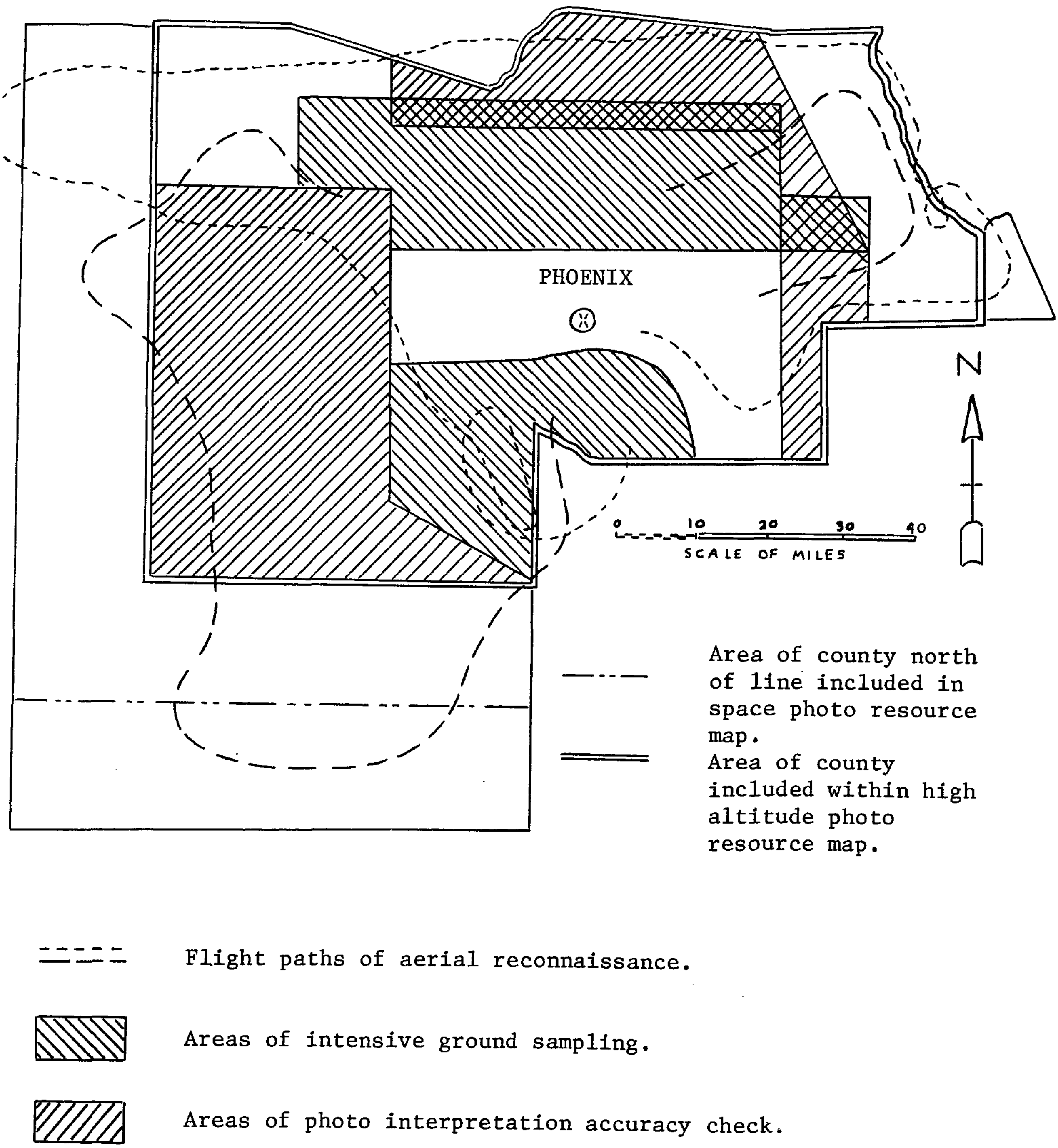
TABLE II.- CONTINUED

| ACTUAL UNITS | INTERPRETED UNITS: 321.11 | 321.21 | 321.22 | 321.23 | 321.32 | 321.41 | 321.9 | 321.93 | 331. | 342.1 | Actual total Number | % Error of Omission |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 321.11 | 17 | | | | | | | | | | 17 | 0 |
| 321.12 | 5 | | | | | | | | | | 5 | 100 |
| 321.15 | 13 | | | | | | | | | | 13 | 100 |
| 321.17 | 1 | | | | | | | | | | 1 | 100 |
| 321.21 | 3 | 27 | 5 | 7 | | | 1 | | | | 43 | 37 |
| 321.22 | | 1 | 17 | 3 | | | | | | | 21 | 19 |
| 321.23 | | 3 | 2 | 26 | | 1 | | | | | 32 | 19 |
| 321.9 | | | | | | | 1 | | | | 1 | |
| 321.92 | | | | | | | 1 | 1 | | | 2 | |
| 321.93 | | | | | | | | 2 | | | 2 | |
| 331.2 | | | | | | | | | 1 | | 1 | |
| 342.1 | | | | | | | | | | 3 | 3 | |
| 361.2 | | | | | | | | | | 1 | 1 | |
| 144 | | | | | | | | 1 | | | 1 | |
| 400 | | | | | 1 | | | | | | 1 | |
| 484 | | | | | 1 | | | | | | 1 | |
| Total Number Interpreted | 39 | 31 | 24 | 36 | 2 | 1 | 3 | 4 | 1 | 4 | 145 | |
| % Error Commission | 56 | 13 | 29 | 28 | | | | | | | | |

TABLE III.- EVALUATION OF HIGH ALTITUDE EKTACHROME PHOTOGRAPHY INTERPRETATION ACCURACY

| Degree of Accuracy | Evaluation | Number of Locations in Sample | Percent of Total |
|---|---|---|---|
| No error | Accuracy check and photo interpretation indicated the same vegetation | 95 | 65 |
| Closely related vegetation types were confused by improper identification of secondary plant species | These errors would have little impact on agriculture or urbanization land use projections | 40 | 28 |
| Moderately related vegetation types were confused by improper identification of major plant species | These errors could have strong impact on agriculture land use projections; the vegetations confused were contained within the microphyll desert portion of the legend | 6 | 4 |
| Apparently distantly related vegetation types were confused by improper identification of physiognomic types | A woodland and chaparral type were confused | 1 | 1 |
| Primary resource was incorrectly identified | Idle agricultural fields or barren stream channel lands were interpreted as naturally vegetated | 3 | 2 |
| | TOTAL | 145 | 100 |

Figure 1.- Location of Ecological Resource Inventory and Classification Activities and Accuracy Check Areas Within Maricopa County, Arizona.



N72-29410



SECTION 117

# THE USE OF KODAK AEROCHROME INFRARED COLOR FILM, TYPE 2443, AS A REMOTE SENSING TOOL

ORIGINAL CONTAINS COLOR ILLUSTRATIONS

by

G. R. Cooper
Department of Botany
University of Maine
Orono, Maine

and

R. L. Bowen and H. W. Gausman
Soil and Water Conservation Research Division
Agricultural Research Service
U. S. Department of Agriculture
Weslaco, Texas

## INTRODUCTION

The use of black and white infrared light sensitive film in "remote sensing" of natural resources is a relatively recent development. It was followed closely with the use of Eastman Kodak's false color infrared film for camouflage detection (1, 2). The film is well known as Kodak Ektachrome Infrared Aero, type 8443[1]. It was made available to interested researchers "over the counter." A new infrared color film, Kodak Aerochrome, type 2443, has replaced the 8443 film (3, 4), providing a new horizon and challenge for remote sensing applications with aerial photography. The 2443 had lower contrast than the 8443 film (3, 4), and allowed the researcher to "probe" deeper into areas that would have appeared as solid black shadows on the 8443 film. The cyan (infrared sensitive) layer of 2443 is approximately 1 1/2 stops slower, at a density of 1.4, than the yellow and magenta emulsion layers.

---

1 Use of a company name by the Department does not imply approval or recommendation of the product to the exclusion of others that may be suitable.

## PROCEDURES AND RESULTS

Test procedures applied to the 35 mm Ektachrome Infrared color film and compared with results for the 70 mm infrared color film indicated that Eastman Kodak may be marketing two different films. When each was processed to a negative, the 35 mm film produced a blue base color, whereas the 70 mm film base color ranged from essentially neutral to a slight magenta. The data reported here are on the 70 mm film unless otherwise indicated.

### COMPARISON OF 8443 AND 2443 FILMS

Because infrared color prints are needed for publication and as a tool for field crews doing "ground truth" work, the development of the new type 2443 Aerochrome Infrared film to a negative was investigated (5). A panel of research workers was asked to select "the print" they would prefer to use from both positive and negative transparencies of the 8443 and 2443 films. Eighty-six percent of the panel indicated a preference for "the print" made from the negative processing of the 2443 film. A reproduction of the test given the panel is portrayed in Fig. 1.

A general comparison of the old 8443 with the new 2443 infrared color film indicated that the 2443 film had a lower contrast and some loss of the vivid coloration that characterized the 8443 film. However, the 2443 film was superior in yielding details among shadows of plant canopies whether processed to a positive or negative. The negative processing, in particular, reveals much more detail in plant canopies than does the old 8443. This is apparent in the examples portrayed in Fig. 1.

### Quality Control and Analysis of Variance of Density Readings of Sensitometric Strips Exposed on an EG and G Mark VI Sensitometer

The quality control of taking and processing photographs was investigated. An EG and G Mark VI sensitometer (Wratten No. 15 filter) was used for exposing the film. A Joyce, Loebl microdensitometer was used to obtain optical density readings of the step wedges printed on the 2443 film. Readings were logged on paper tape for IBM-1800 computer input and subsequent statistical analyses. The negative processing of 70 mm film allowed 21 steps of the step wedge to be accurately measured for all three colors, whereas the positive transparency processing would yield only 19 steps for all colors.

The analysis of variance shown in Table I was conducted on transformed (log base 10) densitometric data from negative transparencies. Considering main effects, wedges, steps, and filters had highly significant variance ($p = 0.01$). Significant differences among steps and filters were expected, but differences among wedges seem undesirable until consideration is given to their means and the interaction of wedges with steps. The optical counts for wedges 1, 2, and 3 were 27.2, 27.7, and 27.0, respectively. The interaction of wedges with steps was not statistically significant, indicating that results were repeatable regardless of the steps or wedges used.

The statistical significance ($p = 0.01$) of the interaction of wedges with filters was mainly caused by the response of wedge 3 with the white filter. Readings that were lower with this combination are believed to be in error. The statistical significance ($p = 0.01$) of the interaction of filters with steps was expected.

Results, therefore, indicate that repeatable densitometric readings can be obtained on sensitometric strips exposed on an EG and G Mark VI sensitometer.

## Processing of Kodak Aerochrome, Type 2443, 70 mm Film to a Negative

This processing requires essentially no modification of the normal C-22 processing to a positive. The film is exposed as it would be for a positive with no apparent gain or loss of film speed. Two modifications are: (a) the developer pH is adjusted to pH of 10.6, and (b) developer time is reduced from 14 to 12 minutes. The result is a clean, unmasked, color negative that is easy to print.

The film base responds to aging at room temperature to produce a magenta tint that becomes more intense with increased storage time at room temperature. Frozen film taken from a freezer, thawed at room temperature, loaded, exposed, and developed immediately shows an almost neutral base coloration with only a 0.10 density. Successive development of individual sensitometric strips, developed individually in a Nikor tank and reel, showed the procedure to be reliably reproducible if temperature, timing, and pH were carefully controlled. Individual printing equipment varies too much to allow recommendations for initial filter packs, but a white light print (no filtration, halogen lamp) will give results that allow an easy assessment of the need for further filtration.

## Processing Kodak Aerochrome Infrared, Type 2443, 70 mm Film to a Positive in Kodak Ektachrome E-4 Chemistry

This was done according to Eastman Kodak recommendations. However, pH of the solutions made up from the 1-gallon and 3 1/2-gallon size packages varied rather widely among lots. Accordingly, the solutions were adjusted to uniform pH values following recommendations of the photographic section of NASA at Houston, Texas. The effects of these variations are still being investigated, and no specific recommendations will be made at this time.

## Other Aspects of Processing Kodak Aerochrome, 2443

The effect of agitation on the E-4 process as applied to 2443 film appears to be more critical than with SO-397 normal color film in the same process and should therefore be carefully standardized and watched for signs of improper agitation.

Research on the storage of 2443 film indicates that film storage conditions are more critical for 2443 than they were for 8443 film. Thus, it is necessary to keep the 2443 film refrigerated or actually frozen for all storage time other than loading, exposing, and processing.

## REFERENCES


1. Applied Infrared Photography. 1968. Kodak Publication No. M-28. Eastman Kodak Company, Rochester, New York. 96 p.

2. Fritz, N. L. 1967. Optimum methods for using infrared-sensitive color films. Photogram. Eng. 33:1128-1138.

3. Data Release. 1971. Eastman Kodak Company, Rochester, New York. 5 p.

4. Earth Observations Division Technical Bulletin, 1970. TF6/TB1, NASA, Manned Spacecraft Center, Houston. 2 p, 4 fig.

5. Pease, R. W. 1969-1970. Color infrared film as negative material. Remote Sens. Environ. 1:195-198.


QF

Table I.- Summary table for the analysis of variance for transformed (log base 10) density readings of sensitometric strips exposed on an EG and G Mark VI Sensitometer.

| Source of variation | DF | MS |
|---|---|---|
| Among runs (R) | 1 | 0.0062 |
| Among wedges (W) | 2 | 0.01140** |
| Steps among wedges (S) | 18 | 3.42589** |
| Among filters (F) | 3 | 2.27717** |
| W x F | 6 | 0.00090** |
| W x S | 36 | 0.00032 |
| F x S | 54 | 0.06694** |
| W x F x S | 108 | 0.00025 |
| Error 1/ | 227 | 0.00025 |

** Denotes statistical significance, p = 0.01

1/ Interactions comprising error

| Source of variation | DF | MS |
|---|---|---|
| W x R | 2 | 0.00005 |
| F x R | 3 | 0.00086 |
| W x F x R | 6 | 0.00144 |
| S x R | 18 | 0.00014 |
| W x S x R | 36 | 0.00024 |
| F x S x R | 54 | 0.00035 |
| W x F x S x R | 108 | 0.00014 |

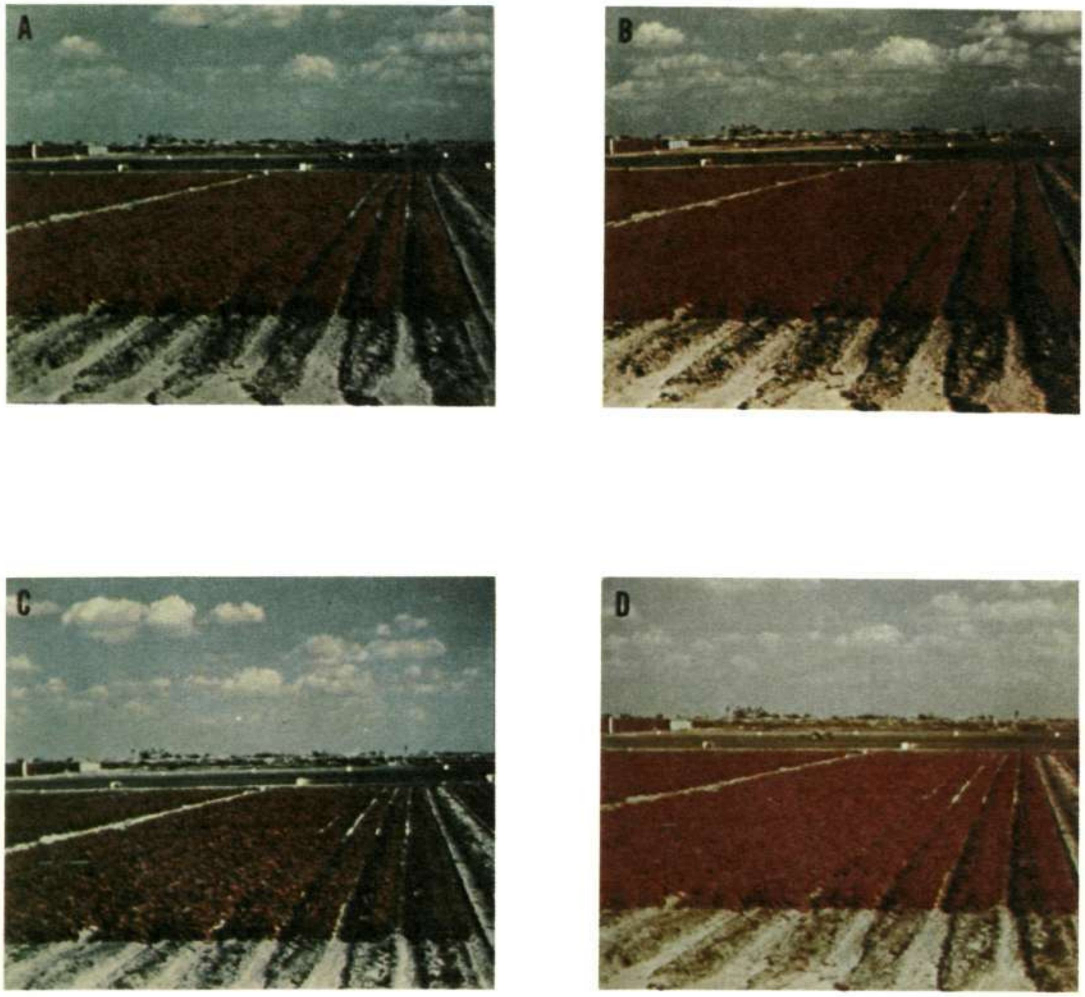



Figure 1.- Representative prints obtained by processing Kodak Ektachrome Infrared Aero, type 8443, and Kodak Aerochrome, type 2443, films to both positives and negatives. Print A is from a positive transparency of 8443, print B is from a negative transparency of 8443, print C is from a positive transparency of 2443, and print D is from a negative transparency of 2443 film.

SECTION 118

# MEASUREMENTS FROM AIRCRAFT TO CHARACTERIZE WATERSHEDS 1/

by

Bruce J. Blanchard 2/
Southern Plains Branch
Soil and Water Conservation Research Division
Agricultural Research Service
U. S. Department of Agriculture
Chickasha, Oklahoma

## INTRODUCTION

In 1961 the Southern Plains Watershed Research Center began studying the hydrology of a 1,130-square-mile segment of the Washita River basin located about half way between the river mouth at Lake Texhoma and the headwater area in the panhandle of Texas. The objective of the research program was primarily the evaluation of hydrologic changes in a major river basin brought about by the construction of systems of flood detention reservoirs on tributary watersheds. The complex nature of such a study necessitates an investigation of the planning and design of the systems as well as a thorough study of watershed and climatic conditions before and after the construction period. As a result, instrumentation for measurement of rainfall, runoff, sediment, ground water, water quality, and climatic conditions in the study area is the most comprehensive system available in any one climatic area.

A thorough hydrologic analysis of the data requires the development and use of mathematical models to adequately describe the movement of water from the time it begins to fall as rain until it is absorbed by the soil surface, evaporates, transpires through plants, or is discharged at the mouth of the river. One of the primary elements of any watershed model is the element which separates the quantity of surface runoff from the quantity of water stored in the surface of the drainage basin (1). The surface soil moisture conditions are a good index of this element. However, no good method exists for adequately monitoring soil moisture because of its large spatial variability. In the last 2 or 3 years, various remote sensing techniques have been investigated to see if they might be able to provide the desired index.

1/ Contribution from the Soil and Water Conservation Research Division, Agricultural Research Service, USDA, in cooperation with the Oklahoma Agricultural Experiment Station. Data for this study have been acquired and furnished by the Earth Resources Division of NASA as part of a study on watershed hydrology.
2/ Research Hydraulic Engineer, USDA, Chickasha, Oklahoma.

Most of the emphasis in remote sensing at this station has been directed toward the measurement of soil moisture, or indirectly, the rainfall-storage capacity of the soil. Other objectives of remote sensing include a search for indicators of pond-water quality, geologic sources of sediment or salt, and rapid methods of mapping seepage.

It should be noted that remote sensing data collected for this study has not been thoroughly analyzed for other applications in hydrologic modeling. Due to limitations on personnel, major emphasis has been placed on the objectives in the order described above.

This report is intended as a summary of the study and observations made in the year 1971 along with the conclusions and concepts developed during this period.

## PROCEDURE

### DATA COLLECTION

Remote sensing data for this study was first gathered by the NASA NP3A and RB57 aircraft on September 29, 1969. The RB57 aircraft was flown at an altitude of 60,000 feet over the entire study area. Two RC8 cameras with color and color infrared film were the primary sensors. A 12-inch focal length Zeiss mapping camera was used on only part of the area, but five Hasselblad cameras with color, color infrared, and black and white infrared film were operated over the entire block. A detailed account of the sensors used, the film-filter combinations, and the coverage of these flights are available in the Mission Reports, Nos. 105 (4) and 106 (8).

The NP3A aircraft was flown at an altitude of 3,000 feet above the ground. Data from the aircraft consisted of microwave line scans in all five frequencies on the multifrequency microwave radiometers. The microwave radiometers were operated with no deviation from the nadir and only vertical polarization was used. Two RC8 cameras, four KA62 cameras, an RS-14 infrared scanner, and a PRT-5 sensor and recorder were also operated on this flight.

Flight lines for the low altitude mission of the NP3A aircraft with the microwave equipment were planned to enable close control of the nadir track and to sense bare ground sites where soil moisture could be sampled. White plastic panels 50 feet long and 5 feet wide on each end of the sample sites were used to mark the flight line. Excellent control of the nadir track was achieved. Rainfall data is available at close intervals along the lines from recording gages used for the watershed study.

Sampling sites for soil moisture were located such that minor deviation of the aircraft from the flight line would not miss the sampled areas. Large bare ground fields were selected where possible and two lines of sample points perpendicular to the flight line (Fig. 1) were staked 100 feet apart. Samples were gathered at points 50 feet apart along these lines. At each point, two samples were taken; one consisted of a 1-inch core of the top 6 inches and another core from 6 to 12 inches. Thirty-three dual samples were obtained for each site. Each sample was tagged with an appropriate site and location number and sealed. Samples were taken to the station laboratory where they were weighed immediately, dried at 105° C, and reweighed. After the samples were analyzed, the mean and variance of the soil moisture percent (on dry weight basis) was calculated for each site (Table I).

Water quality was sampled at 17 ponds along the flight line for subsequent comparison to infrared response. These were collected at or near the time of the flight to avoid changes in water temperature. Temperature readings near the surface of the water were recorded at the time of sampling. The water quality samples were analyzed for total salts, specific salt constituents, and sediment content.

Preliminary data processing and the development of computer programs to convert the microwave analog data to a digital form was done at NASA-MSC. They furnished the microwave data at .4-second intervals on punched cards showing time and corrected antenna temperature for each radiometer. Photographs and output from the infrared scanner were provided as positive transparencies.

## ANALYSIS

A set of photographs in Ektachrome color was used as the base for plotting the ground track. Photo centers were located and transferred to adjoining frames. The radiometer view angles, 16° ± 0.5° for the L band and 5° ± 0.2° for the X through KA bands, were used to calculate the width of track related to the antenna temperatures. Resolution of the microwave data is a function of the integration time of the sensors, the altitude of the sensors, and the speed of the aircraft. On this mission, a 1-second integration time combined with the other factors gave a resolution element approximately 506 feet long by 266 feet wide (Fig. 1) in this instance for the X and KA band radiometers.

A system was developed to synchronize the time of the digital microwave data with points along the ground track. On individual flight lines, it was assumed that the aircraft speed remained constant and therefore the time between the location of all photo centers would also be constant. Computer programs were written to expand or contract the plotted microwave data along the flight line to fit easily detected points associated with lakes and ponds on the photos. A minor change in the length of the time line was necessary and a time shift was required.

A computer plot of the L, X, and KA band microwave data at the same scale as the photos was made such that the transparencies could be positioned over the plot to determine the microwave temperatures associated with the soil moisture data points. The K1 and K2 band radiometers were not functioning properly at the time of the flight and no further attempt was made to use these bands.

The mean of soil moisture at the three depths (0-.5 inch, 0-6 inches, and 0-12 inches) within the resolutional area of each site was plotted against antenna temperature for both the X and KA bands. A similar plot of the soil moisture versus the L band antenna temperatures was also made. Assuming that surface roughness effects might be reflected in antenna temperatures from both the X and KA bands, the difference in temperature between the two bands was plotted versus the soil moisture.

The microwave antenna temperature from data points representing each major land use was averaged for both the X and KA bands (Table II). Land use categories such as roads and farmsteads were not evaluated because the resolution of the radiometers was too poor to adequately represent these spatially compact areas.

The photography and the infrared scanner imagery were studied in an effort to find signatures for any of the common dissolved pollutants found in local ponds and lakes in the area. In addition, data gathered from water samples containing different concentrations of suspended sediments have been analyzed by using visible and infrared spectra. These spectographs were obtained by using the truck-mounted spectrometer at the ARS Remote Sensing Laboratories in Weslaco, Texas. The water samples, beginning with a high concentration of suspended sediments, were repeatedly diluted, sampled, and scanned.

The infrared photographs from the RB57 flight are being used to map eroded soils and gullies. Erosion area in each watershed will be used to test prediction schemes for annual sediment yields.

## RESULTS AND DISCUSSION

Temperatures for the X and KA band radiometers appeared to be most sensitive to the presence of free water on the surface, showing sharp drops in temperature over lakes and ponds. From the study of the microwave plots over the entire flight line and a first look at onboard plots in the X and KA bands from the 1971 flights, there are numerous responses that we are unable to logically explain. However, in repeated flights over the same lines, these anomalies appear to recur. The L band radiometer responded to large bodies of water; however, the temperature drop over a lake was less than it was for the X and KA band. The resolution element of the L band radiometer is also much larger than the resolution element for the X or KA bands and probably accounts for some of the lack of sensitivity evident in the data. In addition, there are anomalies present in the L band data that make its validity questionable even though other studies with passive and active microwave systems (3,5) have shown that the L band radiometer measures soil moisture better than the X band.

## SOIL MOISTURE

The monitoring of soil moisture, especially in the surface few inches, has been difficult. It is the surface few inches that are most critical in controlling runoff. One factor contributing to the problem is the spatial distribution of soil moisture. A search of the literature on soil moisture offers very little information on its spatial distribution near the surface. The spatial distribution will be a function of the moisture level, soil type, and surface gradients. Preliminary analysis indicates that large numbers of gravimetric samples along a flight line will be necessary to adequately define the variance of the area used as a test site. However, if a small sample is used at each test site, the variance will be so large that little confidence can be placed in the mean value; but because of the narrow width of the resolution element, soil moisture means for the sites were calculated from a limited number of samples. A different sampling pattern was used for the 1971 flights to increase the number of samples per resolutional element at very little increase in the total number of samples.

Plots of antenna temperature versus soil moisture content revealed no apparent relationship between the 0- to 12-inch soil moisture and any of the three (L, S, KA) bands. Soil moisture in the top 6 inches was related reasonably well to the X band antenna temperature (Fig. 2), however, the upland soils had lower soil moisture content and more variable antenna temperatures. Extreme scatter occurs when the KA band antenna temperature is used; therefore there is little evidence that this band would be a good index of soil moisture in the surface 6 inches. Plots using the soil moisture in the surface .5 inch did not indicate any correlation with radiometer temperatures.

The X band antenna temperatures showed some correlation with soil moisture in the top 6 inches of soil, therefore the X band data from this study was compared to averaged data representing extremely wet and dry soils from studies at Texas A & M University (2,7). The combined data is in good agreement and encompasses a broader range of soil moisture than that of this study (Fig. 3). Since this relationship appears to be highly significant, it may be possible that the difference between X band temperatures of the same soil under wet and dry conditions may be related to the soil moisture storage capacity.

When the data points on the plot of KA band antenna temperature minus the X band antenna temperature versus soil moisture (0 to 6 inches) are annotated by site number (Fig. 4) there appears to be a separation of the upland soils and alluvial soils. Analyzing the temperature difference between radiometers of different wave lengths is questioned by most people working with microwave data. However, this technique appears to warrant further study as it may lead to a better understanding of the variation in antenna temperatures recorded over soils with low moisture content.

If the difference in X band microwave temperatures for a soil under two different moisture regimes can be shown to be related to the soil moisture and thus to the rainfall-storage capacity, then it may be possible to use the concept in hydrologic modeling. A test of the concept will be made in 1972 using the instrumented watersheds on the Washita River. Once this is established, improved estimates of runoff for use in flood forecasting and flood control design are possible. The X band scanning radiometer will be used to scan the instrumented watersheds during a dry period and again after a major rainfall event. By maintaining a relatively short time interval between scans, any influence from land use should remain unchanged. The aircraft altitude will be varied to produce approximately the same total number of resolutional elements for each watershed enabling a comparison of watersheds with different drainage areas. The mean antenna temperature for the dry condition subtracted from the mean antenna temperature for the wet condition will produce an index related to the storage capacity of the surface. The index, though a numerical value, would be the mean of a very large number of samples and would not require accurate measurement at each sample point. This index will be used in watershed models to replace values presently estimated by hydrologists or taken from empirical tables based on soils, land use, and crop cover.

Considering that radiometric temperatures have some variation, even at higher temperatures, and that the variance of soil moisture measurements is relatively large, any relation between the two variables is going to be encompassed by fairly broad envelope curves. The width of the envelope curves may make sufficiently accurate quantitative measurement of soil moisture from the air a goal that may not be technically feasible for some time.

The microwave data collected by the NP3A aircraft was analyzed to see if different land use classifications could be detected. The mean antenna temperature for both the X and KA bands for each land use classification is shown in Table II. A comparison of the means does not show any significant difference due to crop cover. However, the data show that the most densely covered areas, alfalfa and bermuda and love grass, have the lowest temperatures; whereas, the open or bare ground have the highest. All the other classifications fall between these two groups. Even though the differences are very small, they are in the order expected. Therefore, data gathered at other times of the year with more luxuriant growth and higher moisture content in the crops might show significant differences in antenna temperatures. It is also possible that the influence of cover is not significant and that the differences shown in the table are contradictory due to the relative roughness of the soil surface associated with planting practices rather than the cover itself. Large numbers of sample points over fields with and without the cover would be necessary to separate the influence of moisture and cover. Economic considerations make such tests with airborne equipment impractical. However, field tests with truck-mounted equipment under well-controlled conditions with measurements taken before and after removal of vegetation could be used satisfactorily to test the influence of cover.

## WATER QUALITY

Suspended sediments, particularly clays and fine silts, have been recognized as carriers of other pollutants (6) and as such, they are important in the study of water quality. Analysis of the infrared response from ponds where water quality samples were available did not reveal any means of identifying the common dissolved pollutants found in this area. The response on all film was apparently dominated by the suspended sediment in the water. However, the percent of incident light reflected in the visible and infrared portion of the spectrum was not sensitive to changes in high sediment concentrations similar to that in most streams.

The percent of incident light reflected in the visible light part of the spectrum from water containing suspended sediment does vary with differences in concentration at relatively low sediment loads indicating that reliable estimates of sediment (clays and fine silts) in ponds and lakes can possibly be monitored by aerial photography. Further testing will be necessary to determine effects of other variables such as sediment color on the film response.

## SEDIMENT SOURCE AREAS

The study of sediment source areas as indicated on film has not progressed to a point where quantitative estimates of sediment yield for a watershed can be made. Qualitative assessment of sediment yield as a function of recognizable sediment sources can be made very easily from the high altitude (60,000 ft.) infrared positive transparencies.

## CONCLUDING REMARKS

Antenna temperatures for the X band passive microwave radiometer have been related to soil moisture contained in the surface 6 inches of bare ground. Variation in both soil moisture and the passive microwave antenna temperature appear to limit the possibility of making accurate measurements of soil moisture. Anomalies are present in the microwave response that at present cannot be explained, but these anomalies are reproducible in repeated flights over the same point.

The results of research thus far completed indicate that it may be possible to use microwave remote sensing as an indicator of rainfall-storage capacity in hydrologic models. Scanning watersheds with an X band radiometer for wet and dry conditions within a short period of time will produce a differential response that may be related to the storage capacity of surface soils.

The percentage of incident light reflected in the visible portion of the spectrum was found to be sensitive to differences in low concentrations of suspended sediments in water, thus a technique for estimating the sediment load of ponds and lakes with low sediment concentrations may be feasible.

Qualitative methods of estimating sediment yield from watersheds from high altitude photography appear feasible. Color infrared positive transparencies define erosion areas better than other types of film used in this study.

## REFERENCES


1. Chow, V. T. Hydrologic Determination of Waterway Areas for the Design of Drainage Structures in Small Drainage Basins. Engineering Experiment Station Bulletin No. 462, University of Illinois, March 1962, pp. 72-79.

2. Jean, B. R., Richerson, J. A., Rouse, J. W., Jr., Wiebe, M. L. Microwave Radiometer Measurements of Soil Moisture. Remote Sensing Center, Texas A & M University. Submitted to Remote Sensing Journal.

3. Lundien, J. R. Terrain Analysis by Electromagnetic Means. Report 5, Technical Report No. 3-693, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, February 1971.

4. Mitchell, John. Mission Report for Earth Resources Aircraft Project, Mission 105, NASA-MSC, Houston, Texas, July 1970.

5. Poe, G., Stogryn, A., Edgerton, A. T. Determination of Soil Moisture Content Using Microwave Radiometry. Summary Report 1684R-2, Aerojet-General Corporation, Microwave Division, El Monte, California, February 1971.

6. Robinson, A. R. Sediment Our Greatest Pollutant. Agricultural Engineering, August 1971, pp. 406-408.

7. Rouse, J. W., Jr. Personal communications.

8. von Ehrenfried, Manfred. Mission Report for Earth Resources Aircraft Project, Mission 106, NASA-MSC, Houston, Texas, October 1970.

TABLE I. - MEAN SOIL MOISTURE AND VARIANCE

| | 33 Samples at Each Site | | | | | Small Sample | |
|---|---|---|---|---|---|---|---|
| | 0-.5 in. | 0-6 in. | | 0-12 in. | | 0-6 in.<11 | |
| Site No. | Mean % | Mean % | Variance | Mean % | Variance | Mean % | Variance |
| 1 | 2.1 | 13.4 | 1.8 | 17.0 | 2.6 | 12.8 | 1.7 |
| 2 | 1.4 | 14.1 | 1.5 | 19.6 | 1.5 | 13.5 | 2.4 |
| 3 | 4.1 | 15.1 | 1.5 | 17.8 | 4.0 | 15.0 | 1.2 |
| 4 | 1.0 | 16.0 | 1.6 | 13.2 | 1.6 | 11.2 | 1.3 |
| 5 | 6.5 | 13.4 | 4.3 | 15.4 | 4.9 | 14.1 | 2.0 |
| 6 | 5.9 | 19.8 | 5.4 | 21.0 | 2.1 | 19.0 | 0.73 |
| 7 | 10.8 | 22.9 | 3.8 | 26.0 | 4.2 | 23.5 | 2.3 |
| 8 | 7.0 | 20.5 | 23.8 | 22.4 | 28.8 | 21.9 | 6.6 |
| 9 | 6.2 | 15.7 | 3.9 | 17.2 | 5.0 | 16.3 | 5.0 |

TABLE II. - LAND USE CLASSIFICATION

| Number of Data Points | Class | Mean Antenna Temperature (°K) X Band | KA Band |
|---|---|---|---|
| 450 | Pasture | 278.8 | 290.2 |
| 62 | Eroded Soils and Gullies | 276.7 | 289.8 |
| 141 | Gullied Pastures | 277.8 | 289.8 |
| 167 | Timber | 277.8 | 288.0 |
| 358 | Bare Soil (Tilled Cropland) | 279.1 | 288.9 |
| 81 | Alfalfa | 276.5 | 286.1 |
| 29 | Bermuda and Love Grass | 276.5 | 287.9 |
| 543 | Unclassified | 278.2 | 288.7 |

C 2

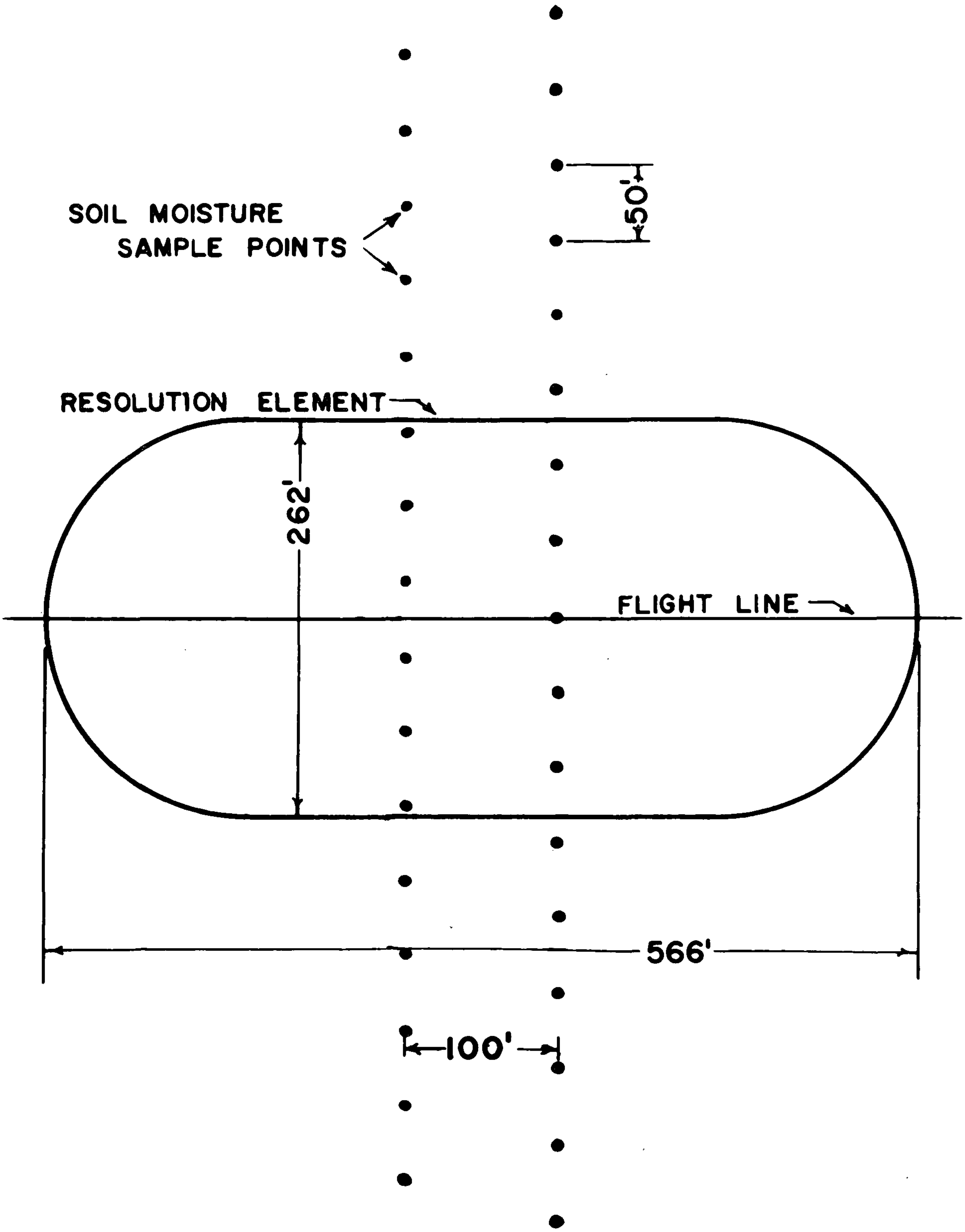



Figure 1. - Map of soil moisture sampling points at a single site with an illustration of the resolution element of the X and KA band radiometer.

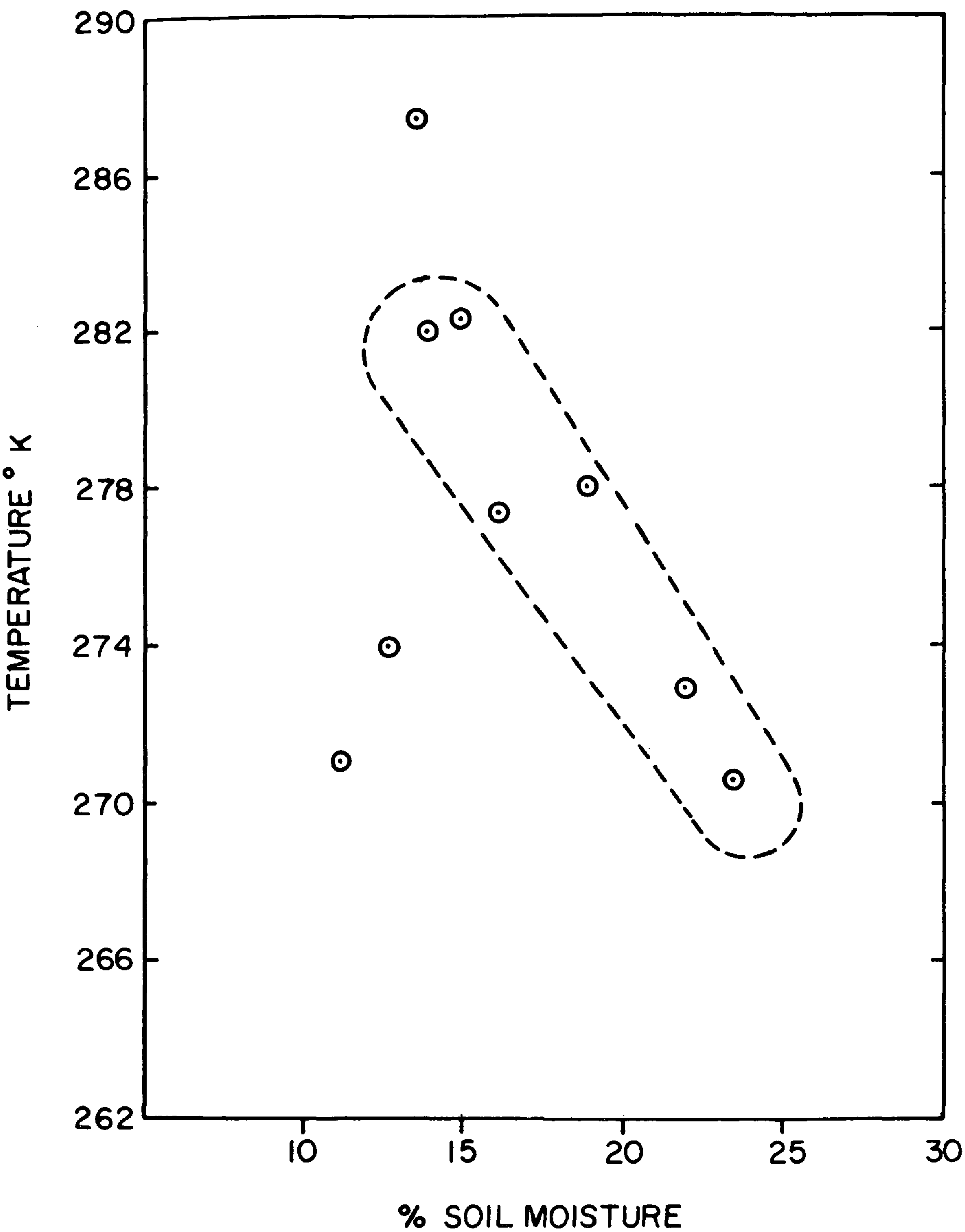



Figure 2. - Relation of X band radiometer antenna temperature to percent soil moisture (Oklahoma soils).

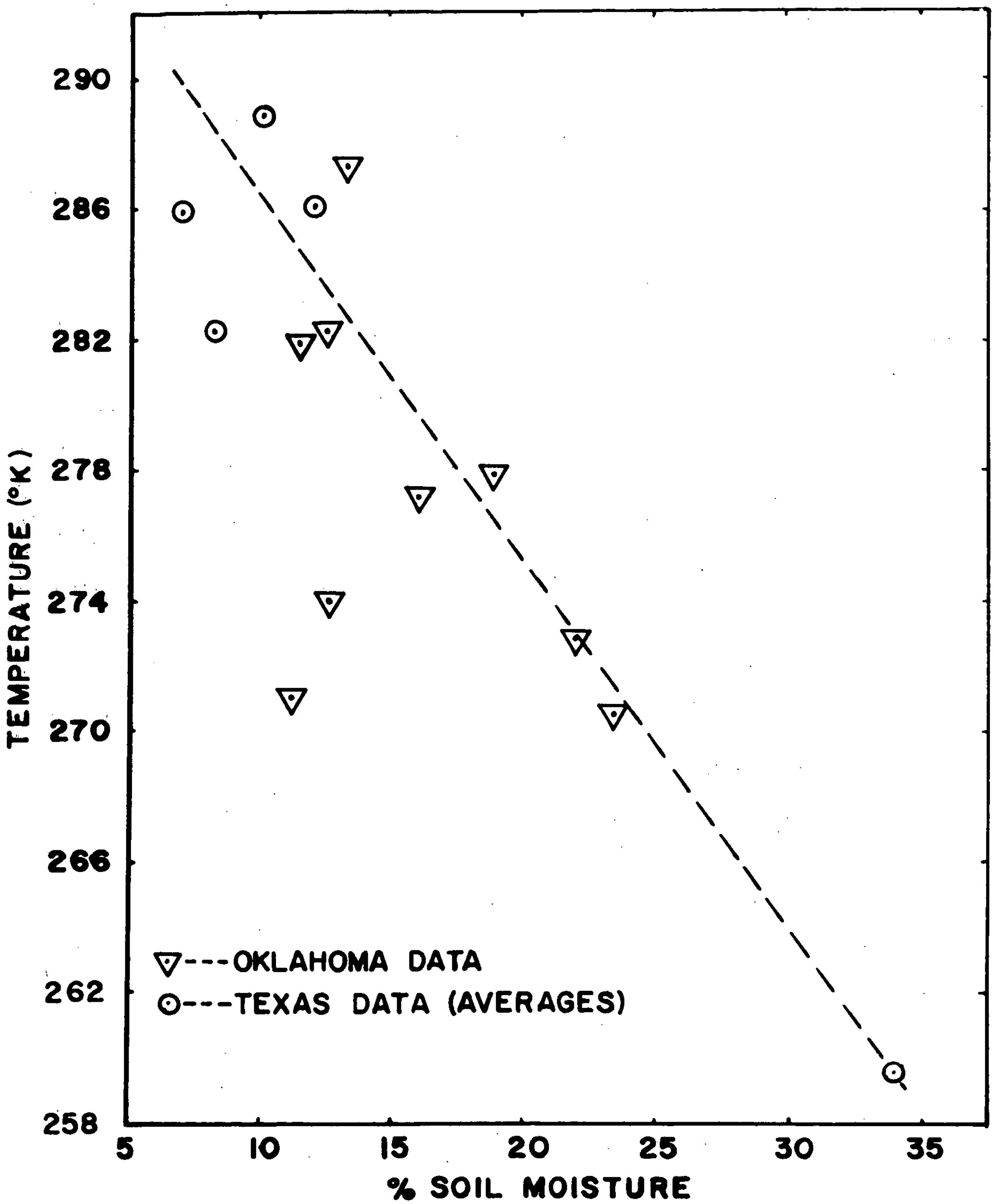



Figure 3. - Relation of X band radiometer antenna temperature to percent soil moisture (Oklahoma and Texas soils).

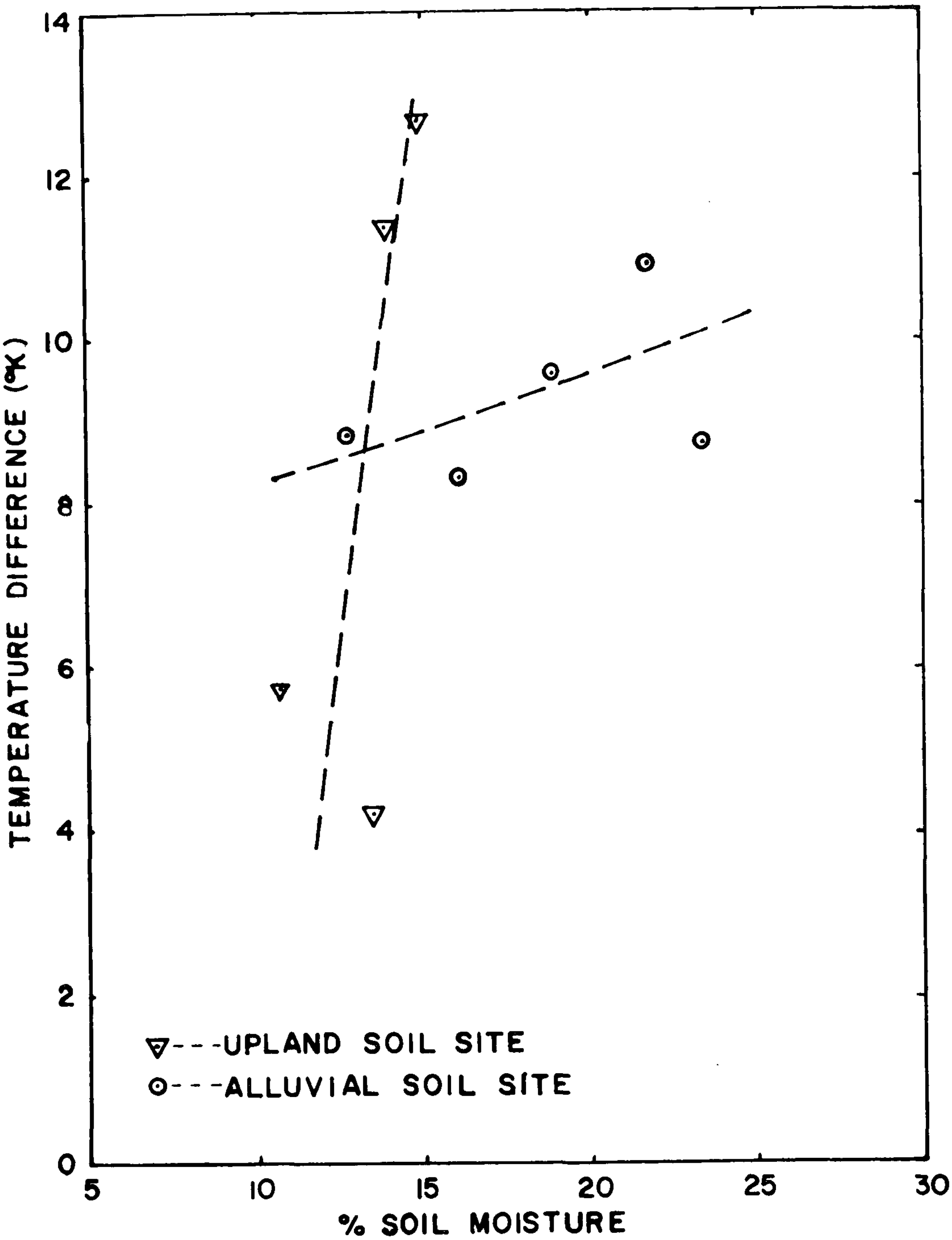



Figure 4. - Differences in antenna temperature (KA band-X band) as related to percent soil moisture (Oklahoma soils)

N72-29412



SECTION 119

# DISCRIMINANT ANALYSES OF BENDIX SCANNER DATA

by

A. J. Richardson, C. L. Wiegand, R. W. Leamer,
A. H. Gerbermann, and R. J. Torline
Soil and Water Conservation Research Division
Agricultural Research Service
U.S. Department of Agriculture
Weslaco, Texas

## INTRODUCTION

Reflectance data from multispectral scanners are used in remote sensing investigations of the U. S. Department of Agriculture at Weslaco, Texas. Long range objectives are: (1) identification of yield-limiting crop and soil conditions, (2) prediction of yields, and (3) automatic recognition of crop and soil types from space. In this study the reflectance data from an aircraft-borne scanner were used to test crop discrimination procedures and to explain sensor response variations in terms of ground truth.

In the spring and summer of 1969, NASA Houston sponsored overflights with the 9-channel Bendix scanner providing calibrated scanner data in the 380- to 1000-nm wavelength interval (WLI). The overflights were made on April 13, May 9, June 6, and July 9 at 2000 feet AGL. These data gave seasonal coverage from the time signals represented mainly the soil background, as a consequence of very young row crop plants, up to full canopy development where signals were dominated by the crop reflectance. NASA contracted with the Bendix Aerospace Systems Division (Ann Arbor, Michigan) to obtain the scanner data, and Weslaco provided the ground truth collection during the flights. Signature processing studies relating scanner data to ground truth were carried out at Ann Arbor (Crawford, et al., 1970; 1970a; Brenda, et al., 1970; Technical Proposal, 1969) and Weslaco. This report summarizes Weslaco's investigations. A more detailed report is in preparation (Richardson, et al., 1972). The full report discusses calibration details of the Bendix scanner and compares Bendix signature studies with Weslaco signature studies on the same data.

## MATERIALS AND METHODS

Five flight lines, listed in Table I by number, length, location, and soil type, were selected for study prior to the 4 Bendix overflights.

Table II lists the fields contained in these 5 flight lines. The fields range from heavy clay to sandy loam soils. Five crop categories--citrus, corn, cotton, sorghum, and bare soil--make up most of the fields in Table II. A number of fields sampled in June were deleted (Table II) for various reasons: (1) scanner channels exceeded range of calibration; (2) sampling line did not intersect field; (3) computer was unable to read data tape; (4) equipment functioned improperly while over field; and (5) sample not representative because of cloud effects. Maturation and harvest of crops and tillage of fields occurred in some categories between the April, May, June, and July flight dates.

Two ground truth reports were prepared. A summary report (Gerbermann, et al., 1970) was prepared in 35 copies and distributed to NASA, Bendix, USDA, and other cooperators interested in using the scanner data. The other report (Gerbermann, et al., 1970a) consists primarily of photocopies of the seasonal ground truth data sheets for each individual field on each flight line.

Ground truth information was punched on IBM computer cards. The Weslaco IBM 1800 computer was used to sort ground truth according to flight date, crop category, and field condition. Sorting according to ground truth grouped all fields into similar categories so that training fields could be randomly selected to represent each crop and soil category. Selected training fields were used to determine principal axis factor scores and pattern recognition algorithm standards. These factor scores and algorithm standards were then used in classification tests involving training and all fields. Selected training fields are listed in the more complete report under preparation (Richardson, et al., 1972).

Digital scanner data were obtained on contract from Bendix. Reflectance data for each field listed in Table II were recorded on digital magnetic tape. One resolution element was sampled at the same angular displacement from nadir on nominally 200 scan lines inside the field boundaries for each field for 8 channels of the Bendix 9-channel scanner. In practice the number of sample elements per field and channel ranged from 44 to 1021 depending on field size. The ninth channel was not operative during any of the overflights.

Principal axis factor analysis was applied to the reflectance data of training fields (Veldman, 1967). This analysis yielded statistics for pattern recognition algorithms. The analysis transforms the original reflectance data into principal axis factor scores. Factor scores have the property that crop and soil differences are maximized using a minimum number of factor scores. In other words, crop and soil variations in the 8 original scanner channels are represented by fewer principal axis factor scores.

Pattern recognition algorithms based on probability error ellipses were computed on factor scores derived from training fields, rather than on the original scanner reflectance data, to take advantage of the fewer variables (Richardson, et al., 1971). The pattern recognition procedure determines the training set ellipse that a candidate set of unidentified transformed reflectance measurements most closely resembles. The ellipse the measurements correspond to identifies that measurement. Any set of measurements not corresponding to any ellipse is placed in a threshold category as not belonging to any crop or soil category tested. The error ellipse threshold was set at the 5% probability level for this study.

Recognition results were listed for training samples and all samples; and for training fields and all fields. Results listed on a per sample basis are a consideration of the identity of every resolution element using error ellipse algorithms. Results on a per field basis is a percent correct recognition classification test according to the category identified most often within a field.

Regression analysis was used to test the effect of percent plant cover (PC) and plant height (PH) on reflectance. All fields were used to calculate the correlation coefficients except citrus and water samples. Citrus (groves and water samples) were deleted from the analysis because it seemed unreasonable to consider trees and water in the same regression analysis with row crops.

Three regression models were used to test for the effect of percent ground cover and plant height on reflectance measurements. The linear model is given by

$$\hat{Y}_i = a_{i0} + a_{i1}x_i \qquad (1)$$

where $i = 1, 2, \ldots, 8$ predictions of PC ($\hat{Y}_i$) or PH ($\hat{Y}_i$) corresponding to the eight channels of reflectance data ($X_i$). The multiple linear model is given by

$$\hat{Y} = a_0 + a_1x_1 + a_2x_2 + \ldots + a_8x_8 \qquad (2)$$

where $\hat{Y}$ is PC or PH and $x_1, x_2, \ldots, x_8$ are the reflectance measurements of the 8-channel scanner. The multiple nonlinear model is given by

$$\hat{Y} = a_0+a_1x_1+a_2x_2 + \ldots + a_8x_8+a_9x_1^2+a_{10}x_2^2 + \ldots + a_{16}x_8^2 \qquad (3)$$

where $\hat{Y}$ is PC or PH and $x_1, x_2, \ldots, x_8$ are the reflectance measurements of the 8-channel scanner.

## RESULTS AND DISCUSSION

The mean factor scores ($\bar{F}_i$) and error ellipse coefficients ($C_{ij}$) used as standard signatures for pattern recognition studies for the April, May, June, and July flights are listed in Tables III and IV, respectively. The indices i and j = 1, 2, ... , NF are the number of factor scores extracted from the factor analysis. These results are based on randomly selected training fields from each crop and soil category. Categories tested are ranked according to the $\bar{F}_1$ means for all flights, since factor 1 accounts for most of the total variance and therefore is the most important factor.

As can be seen in Tables V and VI, the $\bar{F}_1$ means are responsive to the percent plant cover (PC) and plant height (PH) for the categories tested in all overflights. The relation of the $\bar{F}_1$ means (Table III) to PC and PH in April and May is similar. The bare soil category has the largest $\bar{F}_1$ means in April and May. These $\bar{F}_1$ means correspond to the smallest PC and PH for bare soil for the same flights in Tables V and VI. In April the $\bar{F}_1$ means for cotton and sorghum follow bare soil; according to Tables V and VI, the PC and PH for both categories were very low. The categories with the lowest $\bar{F}_1$ means in April and May (Table III) have the highest PC and PH (Table V and VI).

The June and July flights are similar in category structure as shown in Table IV using the $\bar{F}_1$ means. The vegetative categories all have $\bar{F}_1$ means larger than the bare soil category. In general, the high $\bar{F}_1$ means for vegetation correspond to high PC and PH in Table V and VI. Also the low $\bar{F}_1$ means for bare soil correspond to low PC and PH in Tables V and VI. No water samples were taken in July. In both June and July the cotton category ranked first within the vegetation categories and by July cotton was so distinctive that recognition of cotton fields was very accurate.

The percent recognition results in Tables VII and VIII indicate that it is possible to distinguish bare soil, vegetation, and water reliably. For these recognition results, the bare soil category for April was composed of bare soil, cotton, and sorghum fields. For the other three flights, the bare soil category was composed of only uncropped fields. As was expected, higher recognition results were obtained using randomly selected training fields in each category as compared to using all fields. Recognition results on a per field basis were higher than on a per sample basis. These results show that automatic recognition procedures are feasible for general land use applications involving soil, vegetation, and water.

Requirements for more detail of specific vegetation categories will be more difficult to meet. It was not possible to distinguish any specific vegetative category in April or May with any degree of accuracy. In June and July, it was possible to distinguish citrus and cotton, respectively.

Figures 1 and 2 are factor score scatter diagrams for April and May. In general, soil and crop categories have the same arrangement of point clusters. In both diagrams, the cluster of points in the upper right corner, identified with G's, is the water category distribution. Proceeding downward and to the left are the points identifying the bare soil distributions. The vegetative distributions are about midway down and to the left in each diagram. These distributions indicate the difficulty of identifying individual vegetative categories. None of the vegetative categories has a distinctive cluster of points like the water and bare soil categories.

The diagrams in Figs. 3 and 4 are the factor score scatter diagrams for the June and July flight dates. In June, citrus (D's), water (F's) and bare soil (A's) had fairly well-defined clusters of points. Vegetative category distributions other than citrus were confused in June. In July the cotton distribution (A's) had very good separation. These two developments gave 91.0% recognition for citrus in June and 86.4% recognition for cotton in July. In both cases "false alarm" errors were low.

Any number on these diagrams between 2 and 9 means that 2 to 9 samples coincide at that point on the diagram. A percent sign (%) on the diagram indicates that 10 or more samples coincide at that point on the diagram. If a letter prints out, then only one sample occurs at that point on the diagram.

Table IX lists coefficients for correlations of PC and PH with Bendix 9-channel reflectance measurements at each WLI for each flight. In general, there is a better correlation of PC with reflectance measurements than of PH with reflectance measurements. The correlation coefficients using the linear model for individual WLI were usually statistically significant, but they are not strong enough (highest r = .725) to insure accurate predictions of ground cover or plant height. The multiple correlations for the linear and nonlinear model are high enough (highest r = .875) to possibly insure accurate predictions. For PC and PH predictions, April is the worst date. The May, June, and July flight dates have higher correlations.

The reflectance spectra for cotton, sorghum, soil, and water for the April, May, June, and July flights in Figs. 5 and 6 help to explain the correlation results in the visible and infrared WLI. For all 4 flight dates, the reflectance spectra in the visible WLI for cotton and sorghum are lower than the soil spectra. In the infrared WLI, the cotton and sorghum reflectance spectra cross over the soil spectra and become higher. That is, as the vegetative cover increases, the overall reflectance in the visible WLI decreases because vegetation reflects less light than soil in the visible range. On the other hand, in the infrared WLI, the overall reflectance increases as vegetative cover increases because vegetation reflects more light than soil.

The spectral curves for bare soil and water are different for all four flight dates. There were no water samples collected in July. It was thought that these two categories would have the least variable spectra for all flight dates. The spectra for cotton and sorghum changed from one flight date to another as expected since their PC and PH were changing. In April, cotton and bare soil have similar spectra since cotton is newly emerged seedlings that occupy little ground space. Even though cotton and sorghum are planted at the same time, sorghum grows faster, resulting in a higher PC and PH than for cotton at the same age.

## CONCLUSION

Standard signatures were developed using factor scores and error ellipse coefficients that statistically describe crop, bare soil, and water categories for pattern recognition studies. The $\bar{F}_1$ means are the most important factor score for signature development. These means, when ranked in descending order of magnitude, show the relative structure among crop, bare soil, and water categories. April and May as one group and June and July as another group had similar category structure, and corresponded to PC and PH.

Results from pattern recognition studies using these signatures show that it is possible to distinguish bare soil, vegetative, and water categories accurately. In most cases, however, vegetative categories could not be adequately separated from each other. For example, in May it was not possible to distinguish citrus from other vegetation because of the high number of "false alarm" errors from sorghum, cantaloupe, and cotton. The accuracy of identifying citrus was 71.5%, but fields of sorghum, cantaloupe, and cotton were also identified as citrus.

In June, citrus was distinguishable with an acceptable degree of accuracy, 91.0%. For some reason citrus has a fairly distinctive signature in June (Fig. 3), perhaps because it is not growing as virorously as the other vegetative categories. In July cotton could be distinguished from everything else with an accuracy of 86.4%.

In general, it appears that bare soil, vegetation, and water can always be distinguished accurately using the wavelength channels available for this study. Other wavelengths recommended for vegetation discrimination (Allen, Gausman, Wiegand, 1970) were unfortunately, not available.

In some instances, as with citrus in June and cotton in July, field conditions will be such that a particular vegetative category of interest will be recognized accurately.

As shown in Table IX, there is an indication that plant cover and plant height can be predicted using Bendix 9-channel scanner reflectance measurements. For all 4 flights it was possible to predict plant cover more accurately than plant height. For all 4 flights, the visible and infrared WLI have opposite responses to PC and PH. In the visible WLI, as plant cover and plant height increased, reflectance decreased. In the infrared WLI, the opposite response occurred. In the visible WLI, the relatively low reflecting vegetation is covering the relatively high reflecting soil causing the overall reflectance to decrease with increasing plant cover. An opposite situation prevails in the infrared WLI where soil is less reflective than vegetation.

## LITERATURE CITED

Allen, W. A., Gausman, H. W., and Wiegand, C. L. 1970. Spectral reflectance from plant canopies and optimum spectral channels in the near infrared. Third Annual Earth Resources Program Review, Vol. II. NASA Manned Spacecraft Center, Houston, Texas. December 1970.

Brenda, K, J., Morganstein, D. R., and Hanson, D. S. 1970. Signature data processing study final report, BSR 2949. The Bendix Corporation Aerospace System Division, Ann Arbor, Michigan. Vol. III, August 1970.

Crawford, C. L., Dye, R. H., and Hanson, D. S. 1970. Signature Data Processing Study Final Report, BSR 2949. The Bendix Corporation Aerospace Systems Division, Ann Arbor Michigan. Vol. I, August 1970.

Crawford, C. L., and Hanson, D. S. 1970a. Signature Data Processing Study final Report, BSR 2949. The Bendix Corporation Aerospace System Division, Ann Arbor, Michigan. Vol. II, August 1970.

Gerbermann, A. H., Cuellar, J. A., and Leamer, R. W. 1970. Ground Truth Summary, April-July, 1969, Site 32, Weslaco, Texas. Rpt. 69-03. dated December 1, 1969.

Gerbermann, A. H., Cuellar, J. A., and Leamer, R. W. 1970a. Detailed Ground Truth, April-July, 1969, Site 32, Weslaco, Texas. Rpt. 70-01, dated March 2, 1970.

Richardson, A. J., Torline, R. J., and Allen, W. A. 1971. Computer identification of ground patterns from aerial photographs. Proceedings of the Seventh International Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor. May 17-21, p. 1357-1376.

Richardson, A. J., Wiegand, C. L., Leamer, R. W., Gerbermann, A. H., and Torline, R. J. 1972. Bendix 9-channel Scanner Data Studies. In preparation as an SWC Report.

Technical Proposal. 1969. Signature Data Processing Study. BSD 1313. The Bendix Corporation Aerospace System Division, Ann Arbor, Michigan, May 1969.

Veldman, D. J. 1969. Fortran programming for the behavioral sciences, Holt, Rinehart, and Winston, Inc., New York, Publishers. 466 p.

TABLE I.--FLIGHT LINE NUMBERS, LOCATIONS, SOIL TYPES, AND LENGTH OF EACH FLIGHT LINE OVER WHICH BENDIX 9-CHANNEL SCANNER DATA WERE OBTAINED IN 1969.

| Flight line | Location | Soil types present | Line length |
|---|---|---|---|
| No. | | | Miles |
| 1 | Research Farm<br>Highway 88<br>(Mi 5 W & 12 N) | Sandy clay loam | 1 |
| 3 | FM Rd 1015<br>(Mi 3 W from<br>Mi 12 N to<br>Floodway) | Clay<br>Clay loam<br>Fine sandy loam<br>Sandy clay loam<br>Silty clay | 7 |
| 11 | "I" Rd (between<br>Pharr and San Juan)<br>from Exp 83 N for<br>5 mi. | Clay loam<br>Sandy clay loam<br>Fine sandy loam | 5 |
| 12 | FM 1426<br>(E of San Juan)<br>from Rio Grande<br>to Exp 83 | Clay<br>Silty clay loam<br>Silty clay | 7.5 |
| 13 | Highway 281<br>(Military Highway)<br>from Hidalgo to<br>S of Donna then<br>cross country to<br>Int'l Bridge at<br>Nuevo Progreso | Clay<br>Silty clay<br>Silty clay loam | 17 |

TABLE II.--CROP GENERA, WEEDS, BARE SOIL, AND WATER, AND NUMBER OF FIELDS OF EACH BY FLIGHT DATE.

| | Flight date | | | |
|---|---|---|---|---|
| Crop | 4/13 | 5/9 | 6/6[a] | 7/9 |
| Cotton | 73 | 69 | 42 | 73 |
| Corn | 19 | 21 | 8 | 9 |
| Cantaloupe | 7 | 8 | 4 | 1 |
| Citrus | 26 | 25 | 11 | 26 |
| Sorghum | 39 | 46 | 26 | 42 |
| Pepper | 1 | 1 | | 1 |
| Cabbage | 1 | 2 | | |
| Tomato | 3 | 3 | 2 | |
| Native vegetation | 2 | 2 | 2 | 2 |
| Coastal Bermudagrass | 2 | 2 | 2 | 2 |
| Oats | 3 | | | |
| Onion | 11 | 1 | | |
| Bare soil | 31 | 41 | 33 | 49 |
| Weeds | 6 | | | 2 |
| Carrot | 5 | 3 | | |
| Alfalfa | 1 | 1 | | 1 |
| Red cabbage | 1 | 1 | | |
| Flax | 2 | | | |
| Water | 9 | 3 | 6 | |
| TOTAL | 242 | 229 | 136 | 208 |

[a] Flight line 1 not included in mission for this date because scanner channels exceeded range of calibration.

TABLE III.--MEAN VALUES AND ERROR ELLIPSE COEFFICIENTS FOR PRINCIPAL AXIS FACTOR SCORES 1 AND 2 USED FOR PATTERN RECOGNITION TESTS. CROP CATEGORIES FOR THE APRIL AND MAY FLIGHTS ARE RANKED IN DESCENDING ORDER ACCORDING TO $\bar{F}_1$.

| April | Factor score means ($\bar{F}_i$) | | Error ellipse coefficients ($C_{ij}$) x $10^{-2}$ | | |
|---|---|---|---|---|---|
| Categories | $\bar{F}_1$ | $\bar{F}_2$ | $C_{11}$ | $C_{12}$ | $C_{22}$ |
| Water | 1.521 | .119 | .116 | -.150 | 1.586 |
| Bare Soil | 1.196 | .611 | .725 | -.840 | 3.725 |
| Cotton | 1.192 | .618 | 1.096 | .065 | 3.717 |
| Sorghum | .503 | .555 | .183 | -.183 | 3.605 |
| Corn | .371 | .545 | .309 | .389 | 5.427 |
| Citrus | .087 | .517 | .169 | .278 | 4.265 |
| Carrot | -1.209 | .550 | .232 | .220 | 2.925 |
| **May** | **Factor score means ($\bar{F}_i$)** | | **Error ellipse coefficients ($C_{ij}$) x $10^{-2}$** | | |
| Categories | $\bar{F}_1$ | $\bar{F}_2$ | $C_{11}$ | $C_{12}$ | $C_{22}$ |
| Water | 1.830 | -.307 | .163 | .331 | 2.616 |
| Bare Soil | 1.788 | .321 | .118 | -.078 | 2.206 |
| Cotton | .769 | .346 | .269 | -.069 | 2.255 |
| Cantaloupe | .355 | .290 | .343 | .038 | 3.791 |
| Citrus | - .235 | .367 | .078 | .029 | 2.028 |
| Corn | - .671 | .187 | .182 | .139 | 3.339 |
| Sorghum | - .784 | .242 | .123 | .001 | 3.009 |

TABLE IV.--MEAN VALUES AND ERROR ELLIPSE COEFFICIENTS FOR PRINCIPAL AXIS FACTOR SCORES 1 AND 2 USED FOR PATTERN RECOGNITION TESTS. CROP CATEGORIES FOR THE JUNE AND JULY FLIGHTS ARE RANKED IN DESCENDING ORDER ACCORDING TO $\bar{F}_1$.

| June | Factor score means ($\bar{F}_i$) | | Error ellipse coefficients ($C_{ij}$) x $10^{-2}$ | | |
|---|---|---|---|---|---|
| Categories | $\bar{F}_1$ | $\bar{F}_2$ | $C_{11}$ | $C_{12}$ | $C_{22}$ |
| Cotton | 1.404 | -.476 | .439 | .026 | .246 |
| Sorghum | 1.219 | -1.017 | 1.269 | -.147 | .150 |
| Corn | 1.187 | -.428 | .642 | .144 | .198 |
| Citrus | .272 | -1.116 | .207 | -.033 | .215 |
| Bare Soil | -.676 | -.671 | 1.044 | .039 | .090 |
| Water | -1.266 | .099 | 1.119 | -.918 | .925 |
| **July** | **Factor score means ($\bar{F}_i$)** | | **Error ellipse coefficients ($C_{ij}$) x $10^{-2}$** | | |
| Categories | $\bar{F}_1$ | $\bar{F}_2$ | $C_{11}$ | $C_{12}$ | $C_{22}$ |
| Cotton | 2.861 | 1.706 | .428 | -.687 | 3.073 |
| Corn | .503 | 1.075 | .378 | -.293 | 1.519 |
| Citrus | .393 | 1.478 | .139 | .057 | .622 |
| Sorghum | .367 | 1.273 | .427 | .086 | .321 |
| Bare Soil | -.787 | 1.968 | 1.047 | .044 | .475 |

TABLE V.--AVERAGE PLANT HEIGHT ($\overline{PH}$) FOR OVERFLIGHTS IN APRIL, MAY, JUNE, AND JULY FOR THE INDICATED CROP CATEGORIES. ONE STANDARD DEVIATION (s) IS GIVEN FOR EACH MEAN.

| Categories | April | | May | | June | | July | |
|---|---|---|---|---|---|---|---|---|
| | $\overline{PH}$ | s | $\overline{PH}$ | s | $\overline{PH}$ | s | $\overline{PH}$ | s |
| | cm. | | | | | | | |
| Cotton | 6.2 | 3.6 | 22.1 | 15.3 | 54.9 | 18.1 | 90.7 | 35.6 |
| Sorghum | 19.3 | 15.1 | 50.4 | 28.9 | 111.4 | 35.4 | 80.7 | 49.8 |
| Corn | 60.3 | 47.6 | 94.9 | 66.1 | 141.5 | 88.4 | 153.7 | 90.7 |
| Citrus | 278.7 | 145.2 | 283.4 | 148.7 | 359.0 | 66.2 | 284.5 | 142.4 |
| Bare soil | 2.8 | 7.6 | 0.0 | 0.3 | 8.0 | 42.7 | 5.7 | 26.8 |

TABLE VI.--AVERAGE PERCENT PLANT COVER ($\overline{PC}$) FOR OVERFLIGHTS IN APRIL, MAY, JUNE, AND JULY FOR THE INDICATED CROP CATEGORIES. ONE STANDARD DEVIATION (s) IS GIVEN FOR EACH MEAN.

| Categories | April | | May | | June | | July | |
|---|---|---|---|---|---|---|---|---|
| | $\overline{PC}$ | s | $\overline{PC}$ | s | $\overline{PC}$ | s | $\overline{PC}$ | s |
| | % | | | | | | | |
| Cotton | 2.5 | 2.5 | 14.8 | 11.2 | 55.9 | 18.3 | 85.0 | 29.6 |
| Sorghum | 12.6 | 13.3 | 46.8 | 33.8 | 77.9 | 24.9 | 75.9 | 30.2 |
| Corn | 39.2 | 33.6 | 52.3 | 35.2 | 61.0 | 38.0 | 52.8 | 30.3 |
| Citrus | 51.7 | 24.7 | 53.6 | 26.0 | 58.4 | 17.0 | 52.6 | 24.5 |
| Bare soil | 3.9 | 12.7 | 1.1 | 4.1 | 6.4 | 21.4 | 4.8 | 16.8 |

TABLE VII.--RECOGNITION RESULTS FOR THE APRIL, MAY, JUNE, AND JULY FLIGHTS. RESULTS ARE GIVEN SEPARATELY FOR TRAINING SAMPLES AND ALL SAMPLES CONSIDERING BARE SOIL, VEGETATION, AND WATER CATEGORIES ON A PER SAMPLE BASIS.

| | Training samples | | | | All samples | | | |
|---|---|---|---|---|---|---|---|---|
| Categories | April | May | June | July | April | May | June | July |
| | % | % | % | % | % | % | % | % |
| Bare Soil | 81.9 | 88.9 | 94.6 | 92.4 | 78.7 | 80.7 | 81.7 | 87.4 |
| Vegetation | 85.6 | 86.7 | 92.4 | 96.3 | 58.4 | 57.3 | 96.0 | 56.4 |
| Water | 97.5 | 95.3 | 90.4 | - | 95.1 | 93.1 | 89.7 | - |

TABLE VIII.--RECOGNITION RESULTS FOR THE APRIL, MAY, JUNE, AND JULY FLIGHTS. RESULTS ARE GIVEN SEPARATELY FOR TRAINING FIELDS AND ALL FIELDS CONSIDERING BARE SOIL, VEGETATION, AND WATER CATEGORIES ON A PER FIELD BASIS.

| | Training fields | | | | All fields | | | |
|---|---|---|---|---|---|---|---|---|
| Categories | April | May | June | July | April | May | June | July |
| | % | % | % | % | % | % | % | % |
| Bare Soil | 87.4 | 100.0 | 100.0 | 100.0 | 89.5 | 100.0 | 94.0 | 90.6 |
| Vegetation | 100.0 | 96.8 | 100.0 | 100.0 | 73.3 | 88.0 | 98.9 | 99.1 |
| Water | 100.0 | 100.0 | 100.0 | - | 100.0 | 100.0 | 100.0 | - |

TABLE IX.--CORRELATION COEFFICIENTS, r, OF PERCENT GROUND COVER (PC) AND PLANT HEIGHT (PH) WITH BENDIX 9-CHANNEL REFLECTANCE MEASUREMENTS OVER THE 380- TO 1000-nm WLI FOR APRIL, MAY, JUNE, AND JULY FLIGHTS. WATER AND CIRRUS FIELDS WERE NOT USED.

| Wavelength in nm | April | | May | | June | | July | |
|---|---|---|---|---|---|---|---|---|
| | PC | PH | PC | PH | PC | PH | PC | PH |
| | Linear model r: | | | | | | | |
| 380-440 | -.579** | -.429* | -.626** | -.626** | -.677** | -.616** | -.525** | -.449* |
| 440-500 | -.549** | -.417* | -.620** | -.539** | -.725** | -.649** | -.485** | -.421* |
| 500-560 | -.494** | -.389* | -.605** | -.534** | -.675** | -.611** | -.451* | -.390 |
| 560-620 | -.448** | -.361 | -.544** | -.461** | -.636** | -.599** | -.341 | -.302 |
| 620-680 | -.505** | -.392* | -.649** | -.554** | -.699** | -.626** | -.474** | -.401* |
| 680-740 | -.410* | -.336 | -.624** | -.569** | -.627** | -.597** | -.302 | -.268 |
| 740-860 | .467** | .234 | .583** | .485** | .653** | .421* | .590** | .477** |
| 860-1000 | .477** | .242 | .589** | .559** | .708** | .526** | .651** | .531* |
| | Multiple linear model r: | | | | | | | |
| | .721** | .475 | .801** | .707** | .841** | .749** | .835** | .697** |
| | Multiple nonlinear model r: | | | | | | | |
| | .752** | .621** | .819** | .740** | .860** | .788** | .875** | .751** |

* Significant at the 5 percent probability level.
** Significant at the 1 percent probability level.

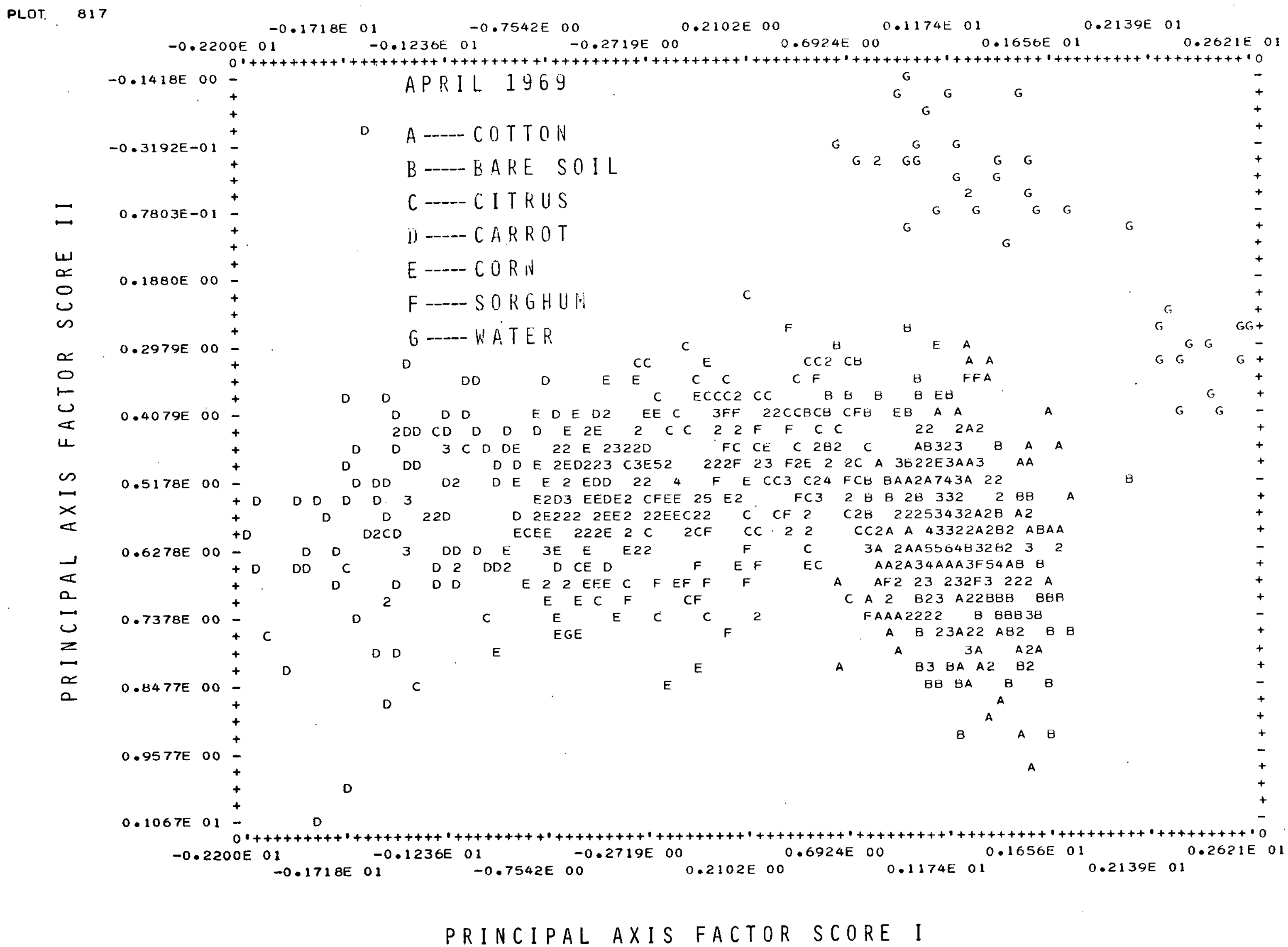



Figure 1.- Scatter diagram of principal axis factor scores 1 and 2 for cotton (A), bare soil (B), citrus (C), carrot (D), corn (E), sorghum (F), and water (G) categories during the April 1969 flight date.

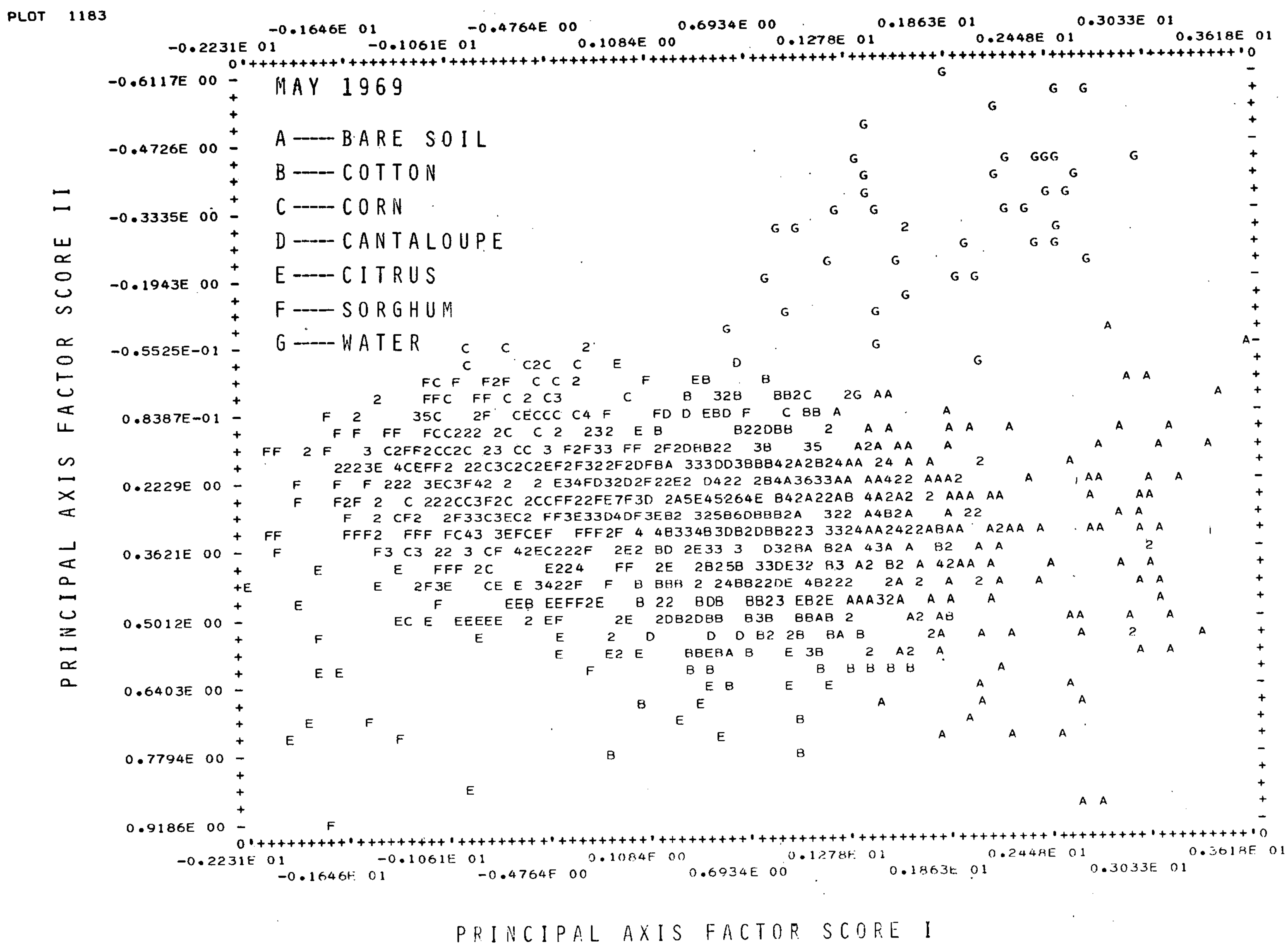
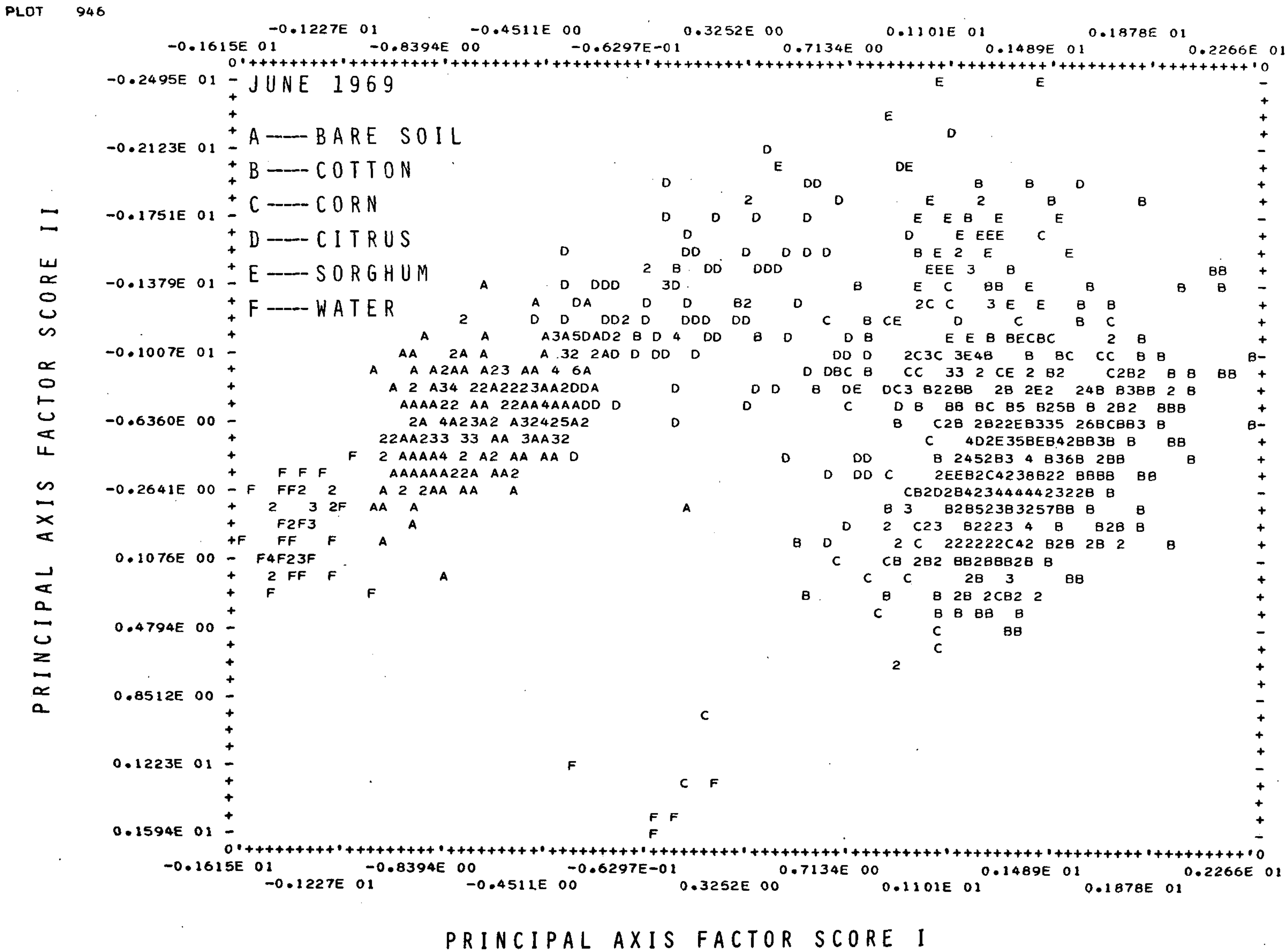



**Figure 2.- Scatter diagram of principal axis factor scores 1 and 2 for bare soil (A), cotton (B), corn (C), cantaloupe (D), citrus (E), sorghum (F), and water (G) categories during the May 1969 flight date.**




RO

Figure 3.- Scatter diagram of principal axis factor scores 1 and 2 for bare soil (A), cotton (B), corn (C), citrus (D), sorghum (E), and water (F) categories during the June 1969 flight date.

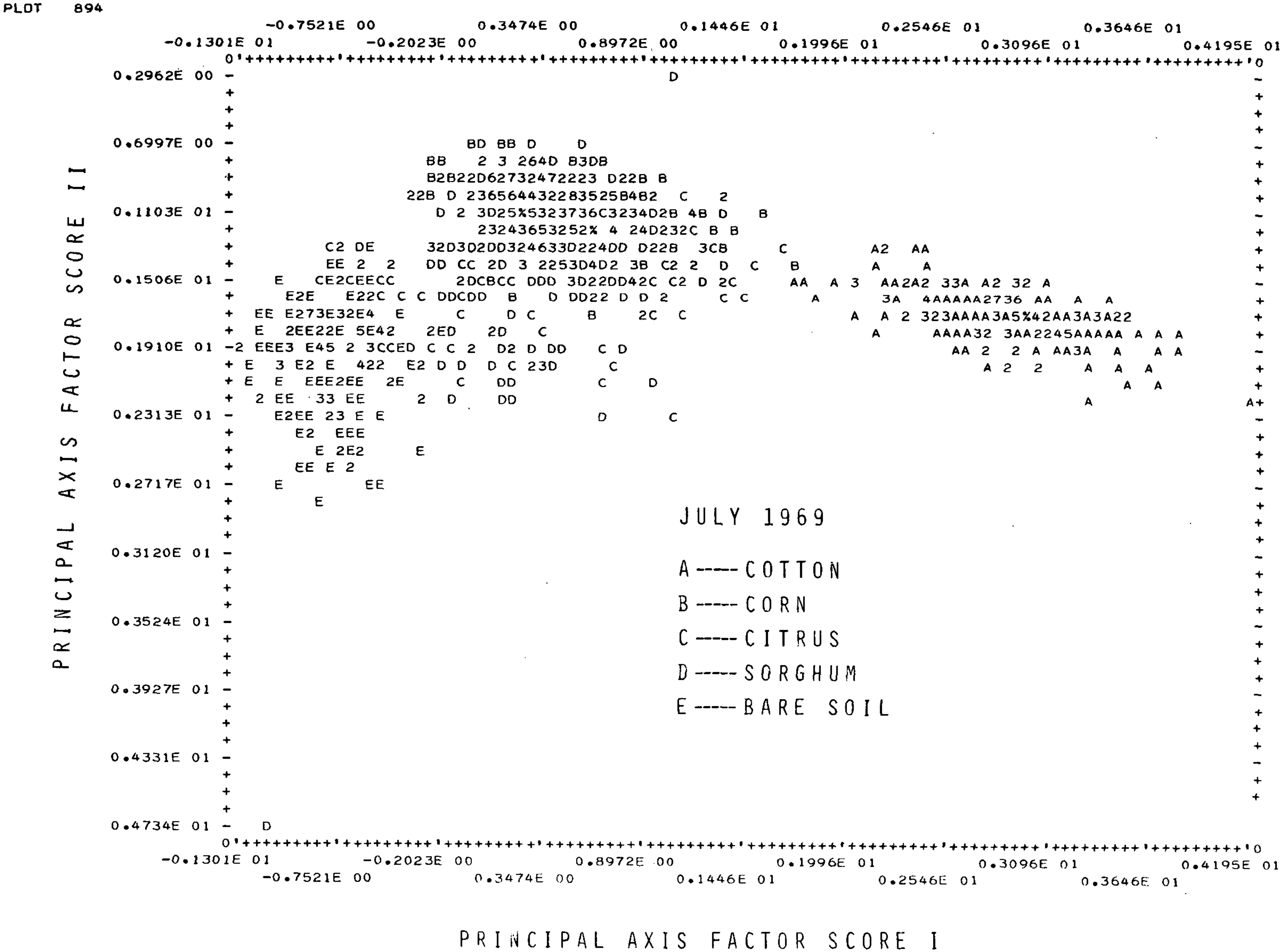



Figure 4.- Scatter diagram of principal axis factor scores 1 and 2 for cotton (A), corn (B), citrus (C), sorghum (D), and bare soil (E) categories during the July 1969 flight date.

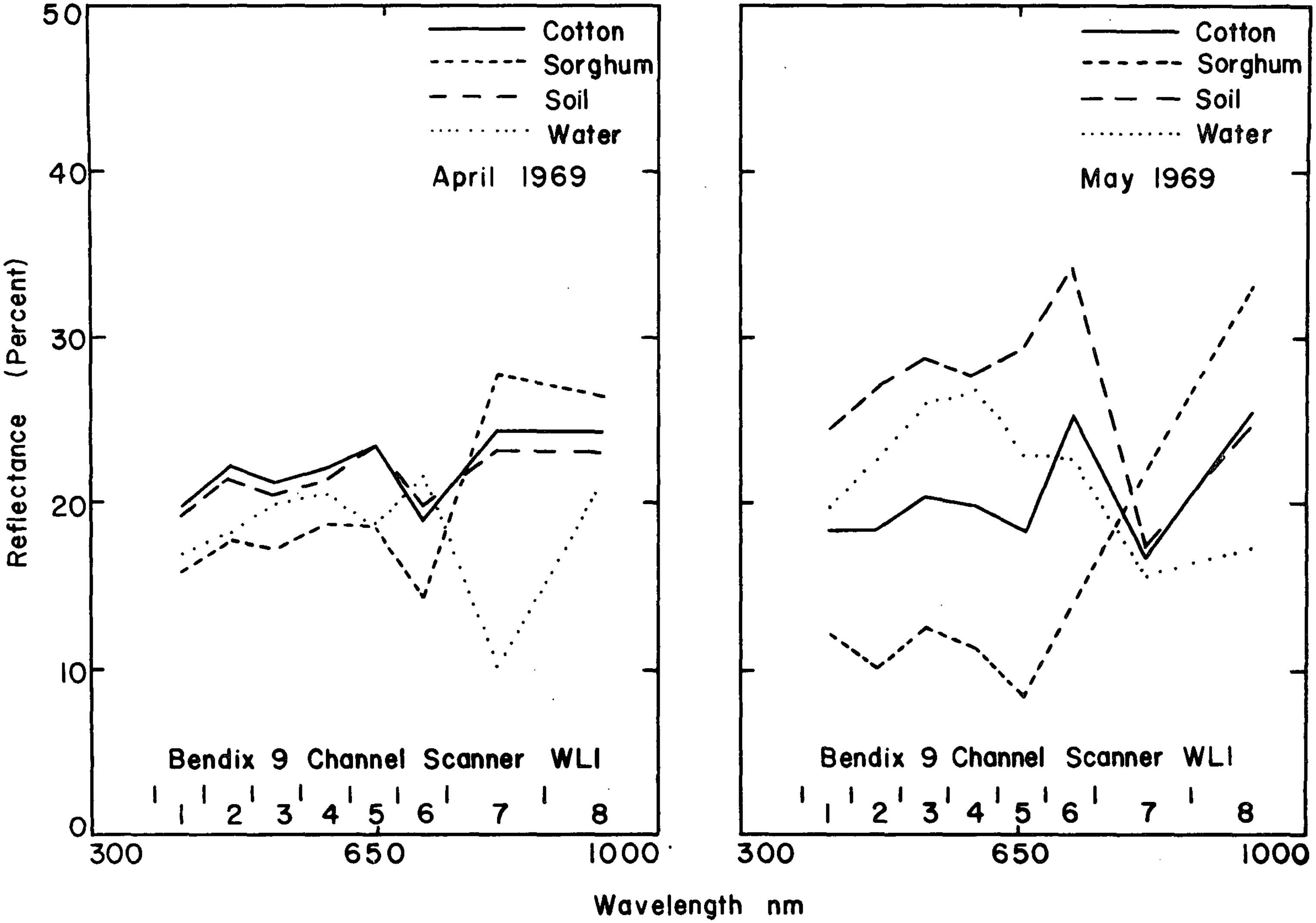



Figure 5.- Reflectance spectra of cotton, sorghum, bare soil, and water using the Bendix 9-channel scanner during April and May 1969.

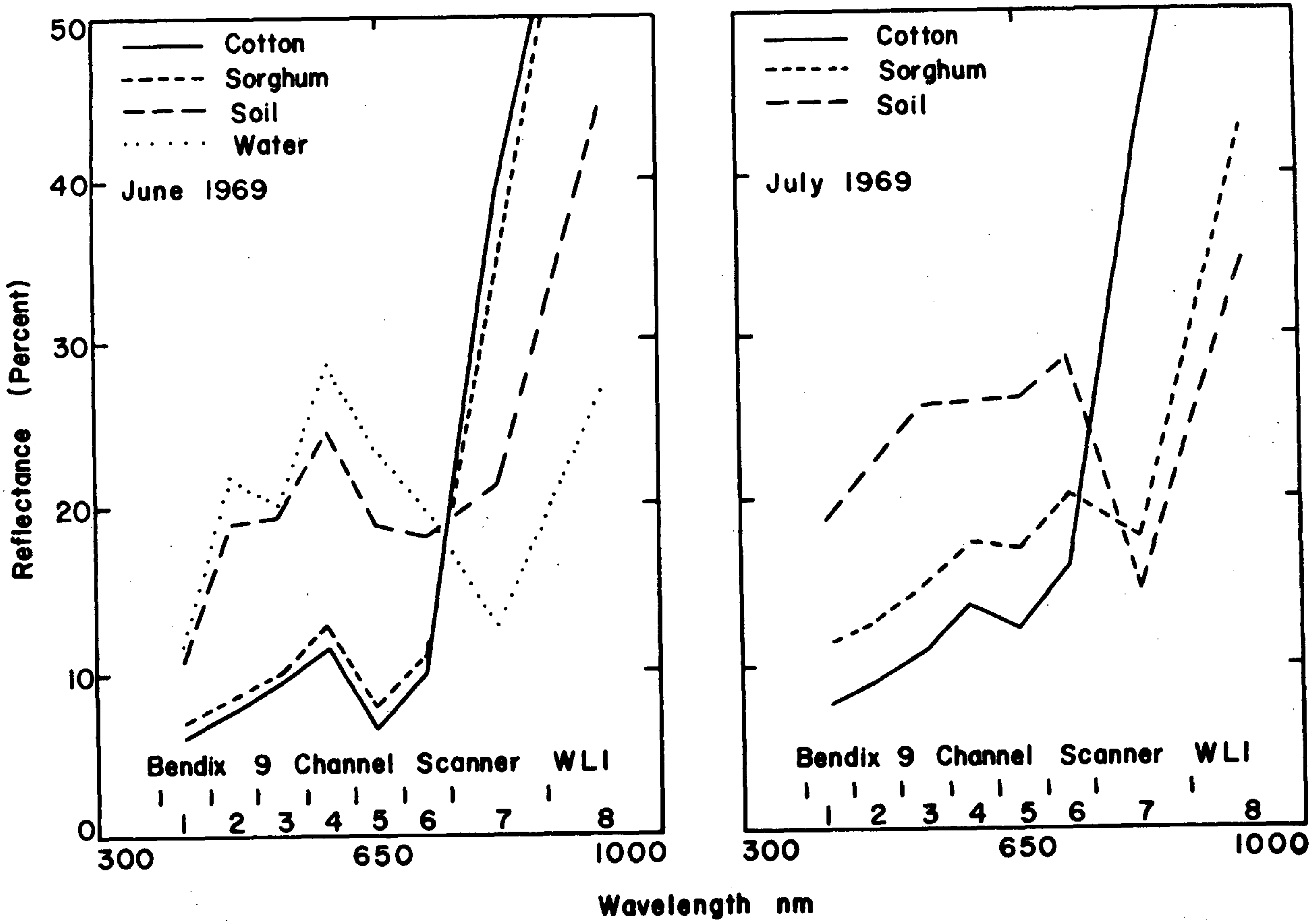



Figure 6.- Reflectance spectra of cotton, sorghum, bare soil, and water using the Bendix 9-channel scanner during June and July 1969.

# SECTION 120

## DEVELOPMENT AND FIELD TEST OF AN ERTS-MATCHED FOUR-CHANNEL SPECTROMETER

by

Frederick P. Weber
Pacific Southwest Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture
Berkeley, California

The design, calibration, and field test of the Forest Service, RS-2 field spectrometer are described. The RS-2 is a lightweight and self-contained instrument designed to obtain simultaneous radiometric data in four spectral bandpasses which are identical to those of the ERTS-A multispectral scanner.

Calibration tests with a precision light source and reflectance standards show the RS-2 is highly accurate in the measurement of target irradiance in each of the four ERTS-MSS bandpasses.

Results are presented of the field test at the Atlanta, Georgia, test site 217 in November 1971 which show the relationship between target spectral irradiance measured simultaneously on the ground with the RS-2 spectrometer and the University of Michigan airborne M-7 multispectral scanner.

The planned application of the Forest Service RS-2 spectrometer for the measurement of target irradiance in the ERTS experiment 226 ("Inventory of forest and rangeland resources, including stress") is discussed.

N72-29413



SECTION 121

# MICROSCALE PHOTO INTERPRETATION OF FOREST AND NONFOREST LAND CLASSES

by

Robert C. Aldrich and Wallace J. Greentree
Pacific Southwest Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture
Berkeley, California

## INTRODUCTION

The first step in an extensive forest inventory such as the nationwide Forest Survey[1] is to separate the forest from nonforest land and possibly stratify forest land by type, volume, or site classes. Until recently this was done on panchromatic or infrared-sensitive films of scales ranging from 1:15,840 to 1:30,000.[2] The benefits from photo stratification can usually be shown in terms of increased operational efficiency, lower inventory costs, and reduced sampling errors. However, two factors continue to limit the use of aerial photographs in forest inventories: One of these factors is the cost of special-purpose aerial photography; the second is the fact that where aerial photographs exist, they usually are out of date before they are needed.

If we are to get the most out of remote sensing for forestry, it must be up to date. Changes in forest area and the condition of forest lands are occurring at an increasing rate, and in highly populated areas the rate of change is becoming alarming. If we use out-of-date photographs in our inventories, conflicts may arise between photo predictions and the ground truth. If these variations are too great there will be little gain, if any, from using the photographs.

What is the solution to this problem? One possible solution is to use small-scale or even microscale aerial photographs for the first-level stratification. Certainly with such a broad area coverage, the photography costs would be reduced, and then it might become attractive to refly photography more often. For example, consider the 1:20,000

---

[1] Forest Survey is a branch in the Division of Forest Economics and Marketing Research, Forest Service, U. S. Department of Agriculture, Washington, D. C. The Forest Survey was authorized by the McSweeney-McNary Forest Research Act of May 22, 1928.

[2] Color negative films are now being used for resource photography on some of the National Forests in the West.

scale photographs supplied by the Department of Agriculture, Agricultural Stabilization and Conservation Service. One of these 9- x 9-inch photographs covers an effective area of approximately 5 square kilometers (2 square miles). If the scale could be reduced to 1:60,000 it would increase the effective coverage to approximately 45 square kilometers (18 square miles)--a 9 time increase. Going even further, a 9- x 9-inch photograph from high altitude, or from space, taken at a scale of 1:400,000 would increase our coverage to approximately 2,000 square kilometers (800 square miles)--a 400 time increase.

But what kind of information will this microscale imagery provide us with and with what accuracy? The research reported in this paper is intended to help answer these questions and is part of a much broader research program seeking solutions to forest inventory problems using remote sensing tools. The test site is located in the southern piedmont land resources subregion southwest of Atlanta, Georgia (Fig. 1).

Funds to support this research have come from both the Forest Service and the National Aeronautics and Space Administration. High-altitude photography was provided by the Earth Resources Aircraft Program at the Manned Spacecraft Center, Houston, Texas.

## METHODS AND PROCEDURES

### GROUND TRUTH

Ground truth for the Atlanta test site consists of a combination of several scales of aerial photography and ground observation points on fifteen 4-mile-square study areas. In March 1970, 1:32,000 Ektachrome Infrared Color Film (8443)[3,4] and 1:12,000 Ektachrome (MS) Color Film (2448), developed to a negative, were taken over each of the study areas. These photographs, plus 1:2,000 and 1:12,000 color taken in April 1969, were used to delineate thirteen land-use and forest classes. Next, over two hundred random points representing all forest and agricultural non-forest classes were selected for ground examination. Among these points were fifty 0.24-hectare (0.6-acre) forest plots taken to establish forest volume, forest type, and site classes. Another eighty forest points were established to record forest types, species composition,

---

[3] Trade names and commercial enterprises or products are mentioned solely for necessary information. No endorsement by the U. S. Department of Agriculture is implied.

[4] This film will be referred to during the remainder of this report as IR color.

crown density, and stand-size classifications. Eighty nonforest agricultural points were located on the ground to record agricultural use at the time of each high-altitude overflight. The details of data collection were reported by Langley, et al. (1) and Aldrich, et al. (2). Final ground truth status maps were made by combining photo interpretation with observations made on the ground.

## PHOTOGRAPHY

At the outset of this study our intentions were to obtain high-altitude photography for the test site at four seasons of the year. A NASA RB-57 flight was planned for early June to represent early summer phenological development when solar radiation was at its peak. Other flights were planned for late summer, fall, and winter to represent different periods of vegetation development. So far, we have been able to obtain photography for only the early summer, late summer, and winter seasons.

The interpretation test reported here uses 1:420,000 scale IR color photography taken with a Hasselblad 70 mm camera (40 mm FL). One major problem for interpreters was caused by differences in film quality and differences in atmospheric conditions at the time of photography. These problems caused considerable variation between film images between missions. For instance, the June (Mission 131) film emulsion had a weak cyan layer. This resulted in an overall hazy blue appearance and what appears to be a poor infrared response (Fig. 2). The September (Mission 141) film was quite good, and the infrared response was enhanced by the addition of a CC-30B color correction filter. This same enhancement filter was used with the March (Mission 158) film, but there was a much more apparent vignetting effect causing the centers of the pictures to be overexposed. This resulted in some problems in resolving low contrast details during interpretation.

## INTERPRETATION

Three interpreters examined the 1:420,000 IR color photographs for all primary study areas covered by each mission. One of these interpreters was a student in biological science with no previous experience in photo interpretation. The other interpreters were experienced and had worked in both the ground and photo interpretation phases of the study for two years. This experience does not bias the study results because of the interpretation techniques that we used.

Each interpreter was given a period of indoctrination and training prior to beginning the test. Two study blocks (blocks 1 and 3) not used in the test were used for training purposes. The interpreters were allowed to examine all available photography including the 1:32,000 and

1:420,000 IR color and ground truth to make correlations for interpretation purposes.

Because the images on 1:420,000 scale imagery are much too small to interpret by normal methods, they were enlarged approximately 13 times using a projection-viewer designed for this purpose (Fig. 3). The device was constructed using a Bell and Howell 35 mm slide projector, an adjustable mirror, and a Polacoat Lenscreen viewing surface. Enlargements of from 8 to 22 magnifications and adjustments for tip and tilt are possible using the instrument as it is presently designed.

Each 70 mm transparency was mounted in a 3 1/4- x 4-inch lantern slide for insertion in the projector. The position of the slide could be adjusted to project the portion of the area to be interpreted.

Interpreters, working independently, outlined and classified the 13 land-use and forest types along each of 18 sample strips. Interpretation always began with the June 1970 (Mission 131) imagery and progressed to the September 1970 (Mission 141) and March 1971 (Mission 158) imagery in that order. The appropriate slide was inserted in the projector and enlarged so that strip beginning and end points, scaled from the ground truth strip maps, coincided with the end points on the projected images. Interpreters were allowed to use magnifying glasses and filters (Wratten 15 and 25) whenever desired to enhance separations between some classes. The land classes were carefully mapped for each strip on acetate overlay material.

## ANALYSIS

Random points selected from the ground truth records were used to check the photo interpretation. The number of points in each land-use class is listed in Table I by season of photography.

Templates were made up for each strip to show the center of each land-use class selected to check photo interpretation. These templates were drawn to scale from the ground truth strip maps. Next, the templates were laid on top of the overlays made by each interpreter and the land-use or forest classification at each point noted and recorded.

Because of distortions inherent in small-scale photographic imagery, and because of limitations in projection systems, we made certain concessions to the interpreter. If the classification shown for the interpreter was on or within 1 millimeter of the correct ground classification (on the enlarged photo), the interpreter was considered correct.

Once all data had been recorded they were punched on IBM cards for computer analysis. Computer tabulations showing the frequency of interpretation by ground classifications were used to analyze the accuracy of interpretation and to point out sources of misclassification. Because the number of observations in some classes was too small for analysis, we have combined them with the land use most closely associated. Thus, class 5 was combined with class 6, class 8 with class 9, and class 13 with class 12.

An analysis of variance was made to determine whether there was a difference between interpreters and whether the season of photography had an effect on the accuracy of interpretation. To make this analysis errors in interpretation were weighted according to the seriousness of the error. For example, a forest point called nonforest would be weighted 2. A pasture point called idle land would be weighted 1. Points correctly classified would be weighted zero. The weighted totals were summarized for interpreters and for seasons of photography.

## RESULTS

While considering the results shown below, the reader should keep in mind that the photo interpretation was done on 1:420,000 scale photography. At first glance the results look rather poor. However, a comparison between these results and the results of studies made in the past using conventional 1:20,000 scale photography shows some good correlations. This comparison is made in the CONCLUSION AND DISCUSSION section of this report.

### LAND-USE CLASSIFICATION

Forest land was separated from nonforest land classes with better than 96 percent accuracy (Fig. 4). As might have been expected the agricultural uses resulted in the poorest land-use classification. Active agriculture (crops and plowed fields) was classified correctly most often on the June photography, but even then the interpreters were right on the average of only 51 percent of the time. On March photography the accuracy dropped to a low of 19 percent. Pasture land is interpreted correctly in 90 percent of all chances on March photography. On June and September photography the accuracy drops to 73 and 75 percent, respectively. Regardless of the season, idle and abandoned land is mapped correctly in approximately 30 percent of the cases. Orchards (pecan and peach) are correct in fewer than 8 percent of the total number of chances.

Urban land, including improved roads, highways, power lines, pipe lines, and land areas in and around communities and cities not qualifying as forest or agriculture, is classified correctly over 97 percent of the time on June photography. The accuracy in September was 94 percent. In March the accuracy fell to 87 percent because some improved roads and highways could not be seen against highly reflective backgrounds.

Water, including small farm ponds, can be detected 91 percent of the time in September (Fig. 4). Less accuracy occurs on June and March photography primarily because of poorer definition due to overexposure of center portions of the photographs.

There were very few forest points misclassified as nonforest (Fig. 5). The season of photography had little effect on the results, and there is little indication that the classification errors can be attributed to anything more than random interpreter error. By taking more care and by improving our training materials we could expect to reduce these errors to almost zero.

Nonforest points were occasionally called forest. This was a particularly serious problem in the idle, abandoned, and orchard land classes. Idle and abandoned land appears a dark gray tone and moderately rough in texture, very much like low-stocked upland hardwood. This similarity is caused by clumps of weeds, blackberries, and noncommercial tree species scattered around with accumulated dead plant debris. It is easy to overestimate the stocking of forest trees and misclassify the land as a result. Another problem is orchards. Pecan and peach orchards look very much like upland hardwoods or abandoned agriculture. For this reason, most orchards were called either forest or idle and abandoned land. Orchards are extremely limited in the test areas, and as a result we had only a small number of samples. It is possible that with more extensive areas in this class, we could have shown better results.

There were very few misclassification errors in the urban and water classes. The most frequent cause of errors in urban classification was small wooded areas (green belts) or garden crops within urban centers (towns). Another cause of misclassification was poor contrast between roads and surrounding agricultural land caused by overexposure, particularly on the March photography. Water was misclassified in almost every instance because of the poor contrast (turbid) water has with surrounding classes particularly in overexposed portions of the photographs.

## FOREST CLASSIFICATION

The accuracy of forest classification varies considerably by type and by season of photography (Table II). Photo interpreters were relatively consistent with one possible exception. Interpreter A was inexperienced and apparently had insufficient training in relating the differences in infrared response on March photography to vegetation types. Despite this, we would have to say that photo interpretation on March photography resulted in the best forest type classification. Interpreters B and C were able to classify pine type correctly 81 percent of the time. However, these two interpreters could classify pine-hardwood type correctly only 33 percent of the time; this low level of accuracy is not unusual even on conventional 1:15,840 and 1:20,000 scale photography. Part of the difficulty is in defining the percentage of pine in the stand.[5] We have found that with the better resolution of 1:12,000 scale and larger scale color and infrared color photography this classification becomes easier and more accurate to identify.

The greatest advantage of high-altitude photography taken in March is the greater accuracy of hardwood type classifications. On the average 60 percent of the stands called bottomland hardwood and 66 percent of the stands called upland hardwoods were classified correctly (Fig. 6). In contrast to this, only 43 percent of the bottomland hardwood was correct on June photography, and only 8 percent was correct on the September photography. The accuracy of upland hardwood interpretation does not appear to vary significantly by the three seasons tested.

There were very few forest points misclassified as nonforest land (Fig. 7). Regardless of the season, no fewer than 96 percent of forest points were correctly classified as forest. Thus, errors in forest type classification were largely errors in judgment of stand stocking. For instance, on the average, interpreters classified 19 percent of the pine stands as upland hardwood on June photography. On September photography the error was 14 percent, and on March photography the error was 14 percent. These are relatively consistent errors and the most serious errors in forest misclassification. They may be reduced in the future by improving photo resolution and developing better keys and definitions of forest types.

The greatest errors in pine-hardwood type classifications were in calling pine-hardwood mixtures upland hardwood (Fig. 7). Sixty-two percent of the pine-hardwood stands were called upland hardwood on June photography, 53 percent on September photography, and 43 percent on March photography. It is apparent that as the percentage of pine is reduced in mixed stands, the greater is the chance for calling the stand hardwood. Also, when deciduous trees (hardwoods) are leafless, there is a

---

[5] Pine-hardwood: 25-50 percent of the dominant stand is in pine; the remainder is composed of hardwood (deciduous) tree species.

greater chance of seeing pine in mixed stands and a greater chance of calling the stands correctly.

Bottomland hardwood type was often called upland hardwood type (Fig. 7). On the other hand, only occasionally (average of 11 percent) was an upland hardwood stand called bottomland hardwood. Misclassification of bottomland hardwood as upland hardwood was greatest in September and the least in March--77 percent as compared to only 24 percent. Therefore, when we want to distinguish between upland and bottomland types, winter photography is most useful.

The results of an analysis of variance show no significant difference between either interpreters or season of photography (Table III). However, season of the year came very close to being significant at the 95 percent level of significance. It was so close that by intuitive reasoning we feel that season did affect the results of this test. Whether or not this effect was due to differences in quality of photography or due to real differences between the land classes we cannot truly say. A summary of the weighted data in Table IV indicates that early summer had the highest scores (poorest interpretation) and winter the lowest scores (best interpretation) with the exception of the one inexperienced interpreter. His total score was higher and indicated that his training on winter photography had not been adequate.

## CONCLUSION AND DISCUSSION

It is always difficult to evaluate the results of a study such as this without some basis for comparison. For instance, how well would interpreters do on conventional 1:20,000 scale panchromatic photographs?

A search of the literature shows only two studies that can be used for comparison. In the first (3), interpreters used basically the same set of criteria to classify land use in southwest Georgia on 1:20,000 panchromatic photographs. In this example 95.5 percent of all forest classifications were correct. This compares with the 96 percent or better accuracy shown in this report. The second study taken from the literature shows the expected accuracy for forest type classification on 1:20,000 scale photography (4). This test made by the TVA in 1952 showed that interpreters could classify three types (pine, mixed, and hardwood) correctly 74 percent of the time. When the forest types used in the present study are combined in a similar way, we can show that 71 percent of the type classifications were correct if made on March photography.

Although these comparisons can hardly be considered conclusive, they should lend some credence to these conclusions:

RE

1. Microscale IR color photography (1:420,000) can be interpreted within reasonable limits of error to estimate forest area.

2. Forest interpretation is best on winter photography with 97 percent or better accuracy. The greatest source of error is in calling abandoned agricultural land forest land, but this error is minimized on winter photography.

3. Broad forest types can be classified on microscale photography. For instance, pine type is correctly identified more than 80 percent of the time on winter photography and at least 70 percent of the time regardless of season. Pine-hardwood cannot be correctly identified better than 25 percent of the time (winter photography) and probably should not be attempted on microscale photography in the future. Bottomland hardwood is correctly classified 60 percent of the time on winter photography but cannot be separated from upland hardwoods at other seasons of the year. Upland hardwood is usually classified correctly 70 percent of the time regardless of season.

4. Active agricultural land is classified most accurately on early summer photography; in this test 51 percent of active cropland and plowed fields were correctly classified. The most frequent error was interpreting cropland as pasture. Fortunately, only a very small percantage of the cropland category was misclassified forest land, and on winter photography this error was at a minimum.

5. Only 6 percent of all nonforest observations (including urban and water) were misclassified as forest. Winter time was the best season for minimizing these errors.

During the coming year we will continue photo interpretation tests using high-altitude aerial photography. Multiseasonal color and IR color photography taken at a 1:120,000 scale will be interpreted and analyzed in a manner similar to that used in this report. We will also concentrate on developing a photo interpretation key for microscale photo interpretation of forest and nonforest classifications.

## REFERENCES

1. Langley, P. G., R. C. Aldrich, and R. C. Heller. 1969. Multistage sampling of forest resources by using space photography--an Apollo 9 case study. Second Annual Earth Resources Aircraft Program Status Review. Vol. 2. NASA Manned Spacecraft Center, Houston, Texas. 28 pp., illus.

2. Aldrich, R. C., W. J. Greentree, R. C. Heller, and N. X. Norick. 1970. The use of space and high-altitude aerial photography to classify forest land and to detect forest disturbances. Annual Progress Report, For. Remote Sensing Lab. for Nat. Resource Survey Prog., NASA, by the Pacific Southwest Forest and Range Experiment Station. 36 pp., illus.

3. Aldrich, R. C. 1953. Accuracy of land-use classification and area estimates using aerial photographs. Jour. Forestry. 51(1):12-15.

4. Bateson, A. R. 1952. A test of aerial photography for forest inventory purposes in the Tennessee Valley. Report No. 205-52. Forestry Investigations Branch, Tennessee Valley Authority, 34 pp.

TABLE I. - NUMBER OF RANDOM CHECK POINTS IN EACH LAND-USE CLASS BY SEASON OF PHOTOGRAPHY

| SEASON | LAND USE[1] | | | | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | |
| Early Summer (June) | 69 | 37 | 40 | 54 | 5 | 23 | 30 | 10 | 35 | 4 | 22 | 13 | 1 | 343 |
| Late Summer (Sept) | 59 | 33 | 16 | 45 | 7 | 8 | 20 | 6 | 22 | 0 | 18 | 7 | 0 | 241 |
| Winter (March) | 60 | 28 | 36 | 47 | 15 | 23 | 28 | 9 | 29 | 3 | 21 | 11 | 1 | 311 |

[1] 1 - Pine
2 - Pine-hardwood
3 - Bottomland hardwood
4 - Upland hardwood
5 - Crop
6 - Plowed field
7 - Pasture
8 - Idle
9 - Abandoned
10 - Orchard
11 - Urban
12 - Turbid water
13 - Clear water

TABLE II. - ACCURACY OF FOREST TYPE CLASSIFICATION BY PHOTO INTERPRETER AND BY SEASON

| SEASON[1] | PHOTO INTERPRETER | FOREST TYPE[2, 3] 1 (P) | 2 (PH) | 3 (BH) | 4 (UH) |
|---|---|---|---|---|---|
| | | - - - - percent correct - - - - | | | |
| June | A | 71 | 0 | 55 | 61 |
| | B | 70 | 11 | 25 | 72 |
| | C | 67 | 0 | 48 | 71 |
| | Mean | 69 | 4 | 43 | 68 |
| September | A | 79 | 12 | 6 | 74 |
| | B | 83 | 15 | 13 | 67 |
| | C | 81 | 33 | 6 | 71 |
| | Mean | 81 | 20 | 8 | 70 |
| March | A | 67 | 7 | 53 | 55 |
| | B | 80 | 28 | 64 | 79 |
| | C | 82 | 39 | 64 | 64 |
| | Mean | 76 | 25 | 60 | 66 |

[1] Seasons tested:

June - early summer
September - late summer
March - late winter

[2] Forest type:

Pine (P) - 1
Pine-hardwood (PH) - 2
Bottomland hardwood (BH) -
Upland hardwood (UH) - 4

[3] The number of observations by forest type is shown in Table 1.

TABLE III. - ANALYSIS OF VARIANCE FOR THREE INTERPRETERS AND THREE PHOTOGRAPHIC MISSIONS

| SOURCE OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARE | F | PROBABILITY OF F[1] |
|---|---|---|---|---|---|
| Interpreters | 323.5557 | 2 | 161.7778 | 2.2331 | 0.7768 |
| Season | 876.2217 | 2 | 438.1108 | 6.0475 | 0.9383 |
| Error | 289.7783 | 4 | 72.4446 | ---- | ---- |
| Total | 1489.5557 | 8 | ----- | ---- | ---- |

[1] This value must be equal to or greater than 0.9500 to be significant at the 95 percent level of significance or equal to or greater than 0.9900 to be significant at the 99 percent level of significance.

TABLE IV. - TOTAL WEIGHTED INTERPRETATION SCORES FOR THREE INTERPRETERS BY SEASON OF PHOTOGRAPHY

| SEASON OF PHOTOGRAPHY | WEIGHTED SCORES[1] | | |
|---|---|---|---|
| | INTERPRETER 1 | INTERPRETER 2 | INTERPRETER 3 |
| Early Summer (June) | 122 | 122 | 118 |
| Late Summer (September) | 105 | 107 | 91 |
| Winter (March) | 116 | 90 | 90 |

[1] Lowest score is best interpretation

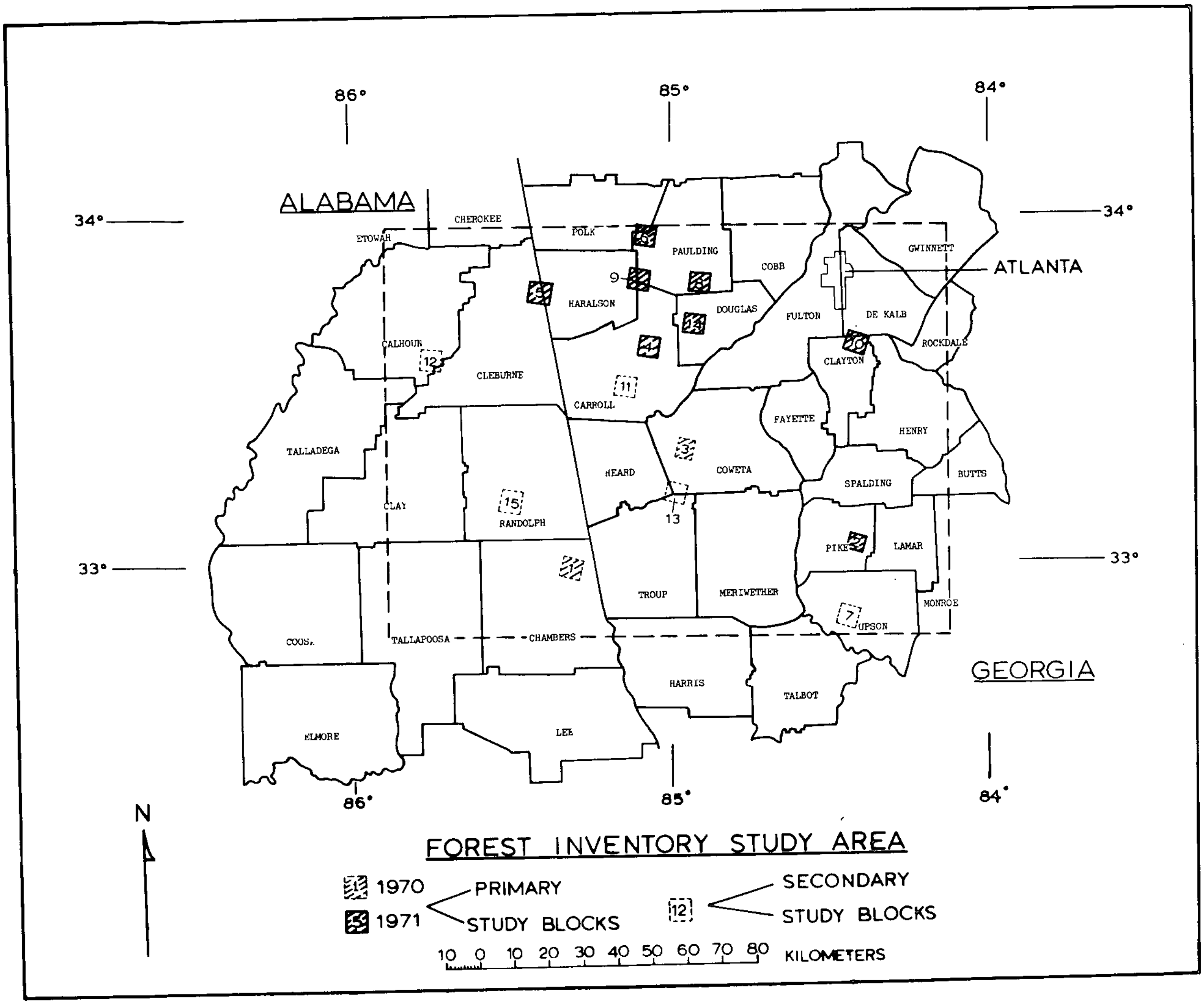



Figure 1.- The Atlanta test site includes all or portions of 27 counties in Alabama and Georgia. Eight intensive study areas used in this report are shown with heavy hatch marks and solid boundaries. Two additional intensive study areas (hatch marked) were dropped for insufficient high-altitude photographic coverage. The remaining study blocks (secondary) will be used to test interpretation models in another phase of the study.

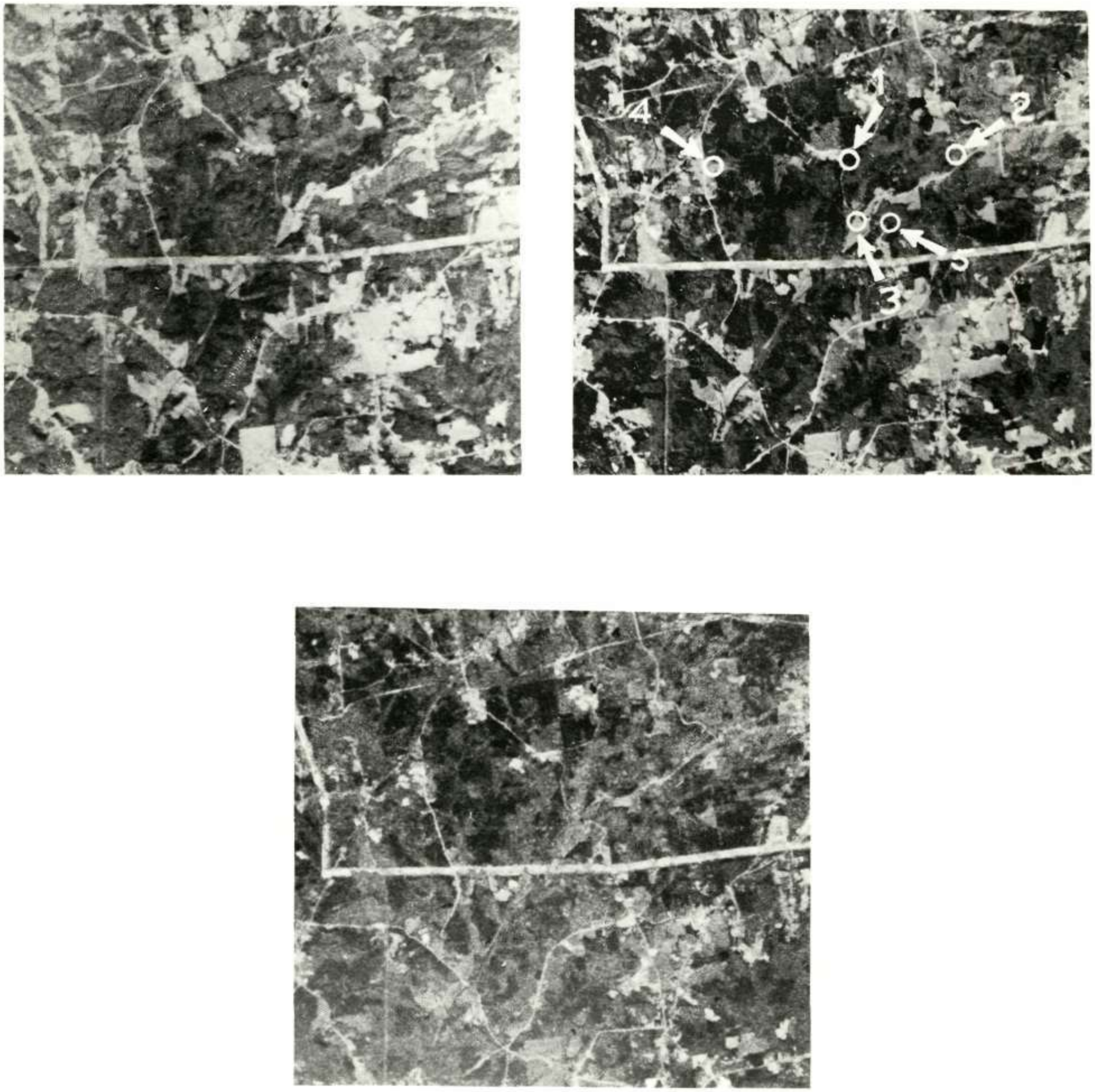



Figure 2.- These three 1:420,000 scale IR color photographs for study block 14 represent the quality of imagery used in this study: (A) June 8, 1970, (B) September 14, 1970, (C) March 5, 1971. Three forest and two nonforest classes are pointed out in (B): (1) pine, (2) upland hardwood, (3) pasture, (4) abandoned, and (5) bottomland hardwood.

Figure 3.- This projection-viewer was used to enlarge 1:420,000 scale photographs to coincide with 1:32,000 ground truth strip maps; (A) Bell and Howell 35 mm projector, (B) adjustable mirror, (C) adjustable viewing surface, (D) focusing adjustment, and (E) pulley for adjusting mirror distance for scaling purposes.

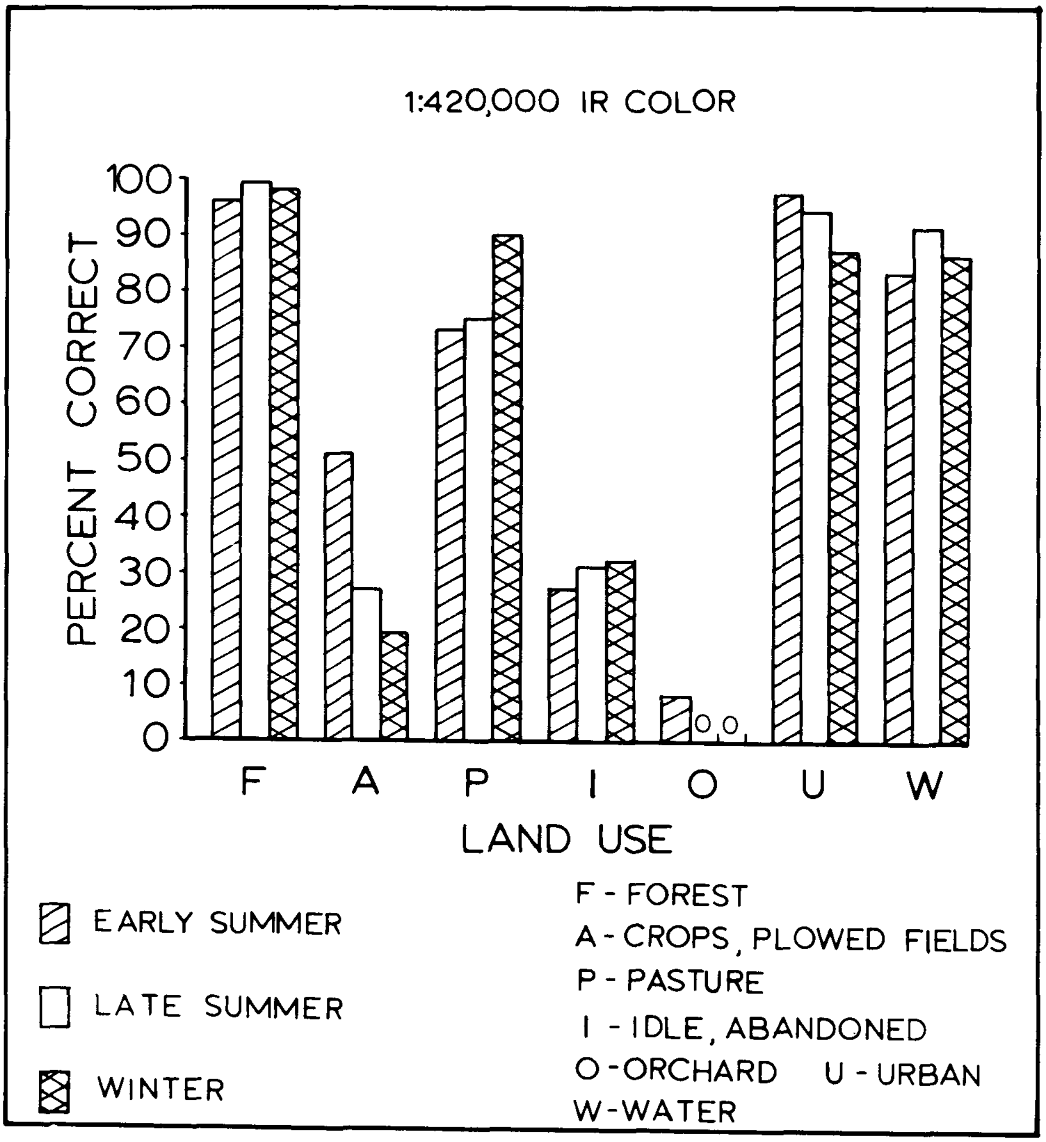



Figure 4.- The average accuracy is shown for three interpreters classifying land use on 1:420,000 IR color photographs taken during three seasons. Note that only in crops and plowed fields is there a significant difference that might be attributed to season. June, or early summer photography, appears to give the greatest accuracy.

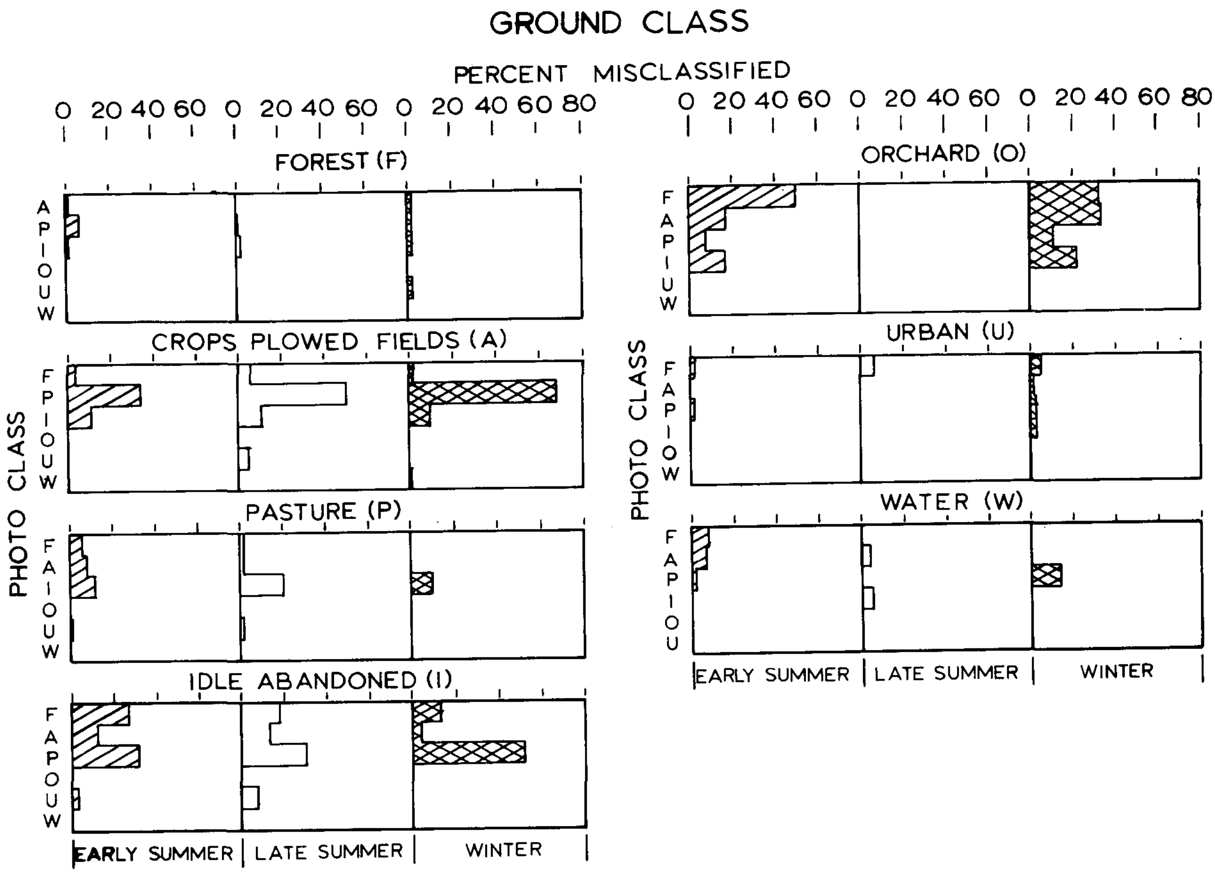



Figure 5.- This chart indicates the percentage (average of three interpreters) of all nonforest points that were misclassified by land use and season of photography. Note that active cropland and plowed fields and the idle and abandoned land are most often misclassified as pasture land.

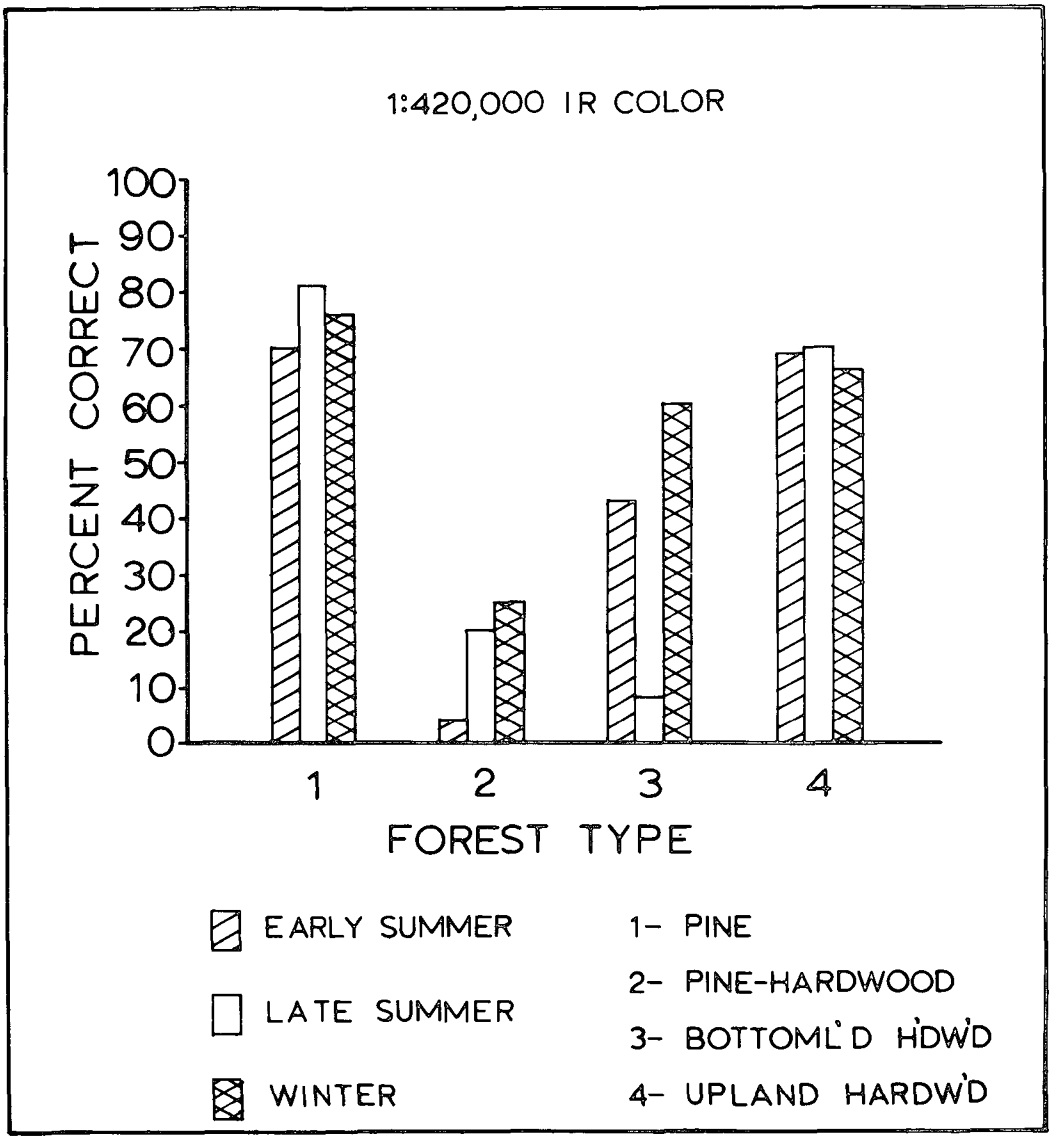



Figure 6.- This chart shows the average accuracy for three interpreters classifying forest types on 1:420,000 IR color photographs taken during three seasons. Note that forest types are generally most accurate on March photography.

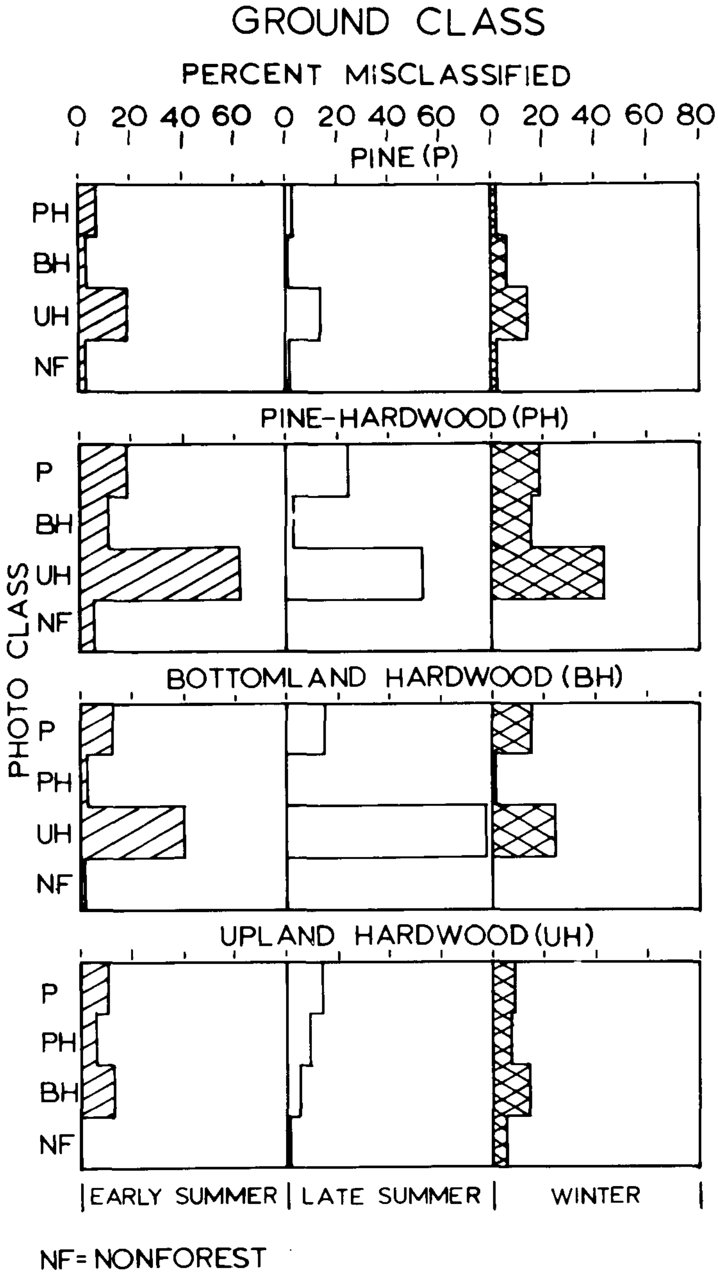



Figure 7.- The percentage (average for three interpreters) of all forest points that were misclassified by type and season of photography. Note that pine-hardwood and bottomland hardwood types are most frequently misclassified. In both cases they are usually called upland hardwood by interpreters.

# POTENTIALITY FOR OBTAINING PORIA DISEASE SIGNATURES IN THE OREGON CASCADES FROM ORBITAL ALTITUDES

by

John F. Wear

Pacific Southwest Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture
Berkeley, California

## INTRODUCTION

A significant step upward is the discovery of a prime photographic signature indicator of an important forest disease in valuable Douglas-fir stands of the Pacific Northwest. The new disease signature has been verified by a multidisciplinary team of scientists to be the direct result of the Poria weirii root-rot syndrome in the Douglas-fir and hemlock stands of the high Cascades in Oregon. It is readily discernible on small-scale suborbital photography and has good potential for detection from earth-orbiting satellites or remote sensing platforms. Let us look at the estimated disease impact on the forest resources, the problem from the ground level, the remote sensing study methodology, and the appearance of the discrete signature on various photo scales.

## DISEASE IMPACT

Protecting our forest resources from the depredations of forest diseases, forest insects, and forest fires is a continuous struggle involving man and the environment. On the basis of total impact (Table I), diseases rank first, insects second, and fire third. The spectacular and destructive forces of fire always excite public attention while the slow insidious activity of forest diseases and forest insects are of lesser concern. However, this attitude is changing with the ever-increasing need for more natural resources to meet public demand and the more intensive management of forest lands by Federal, State, and private agencies. We cannot afford to ignore timber losses in the United States, regardless of the cause.

Poria weirii (Murr.) root-rot disease is responsible for devastating some 170 millions of board feet (Table II) of old-growth and second-growth Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) annually. This represents the amount of lumber needed to replace nearly all the homes in Houston each year.

## PORIA DISEASE FACTORS

*Poria* root rot disintegrates the root system of trees gradually (Fig. 1) until the tree topples over or is blown over. Infection spreads radially from an infection center by mycelial fungii at the rate of approximately one foot per year, makes contact with other tree roots, and continues the cycle to fell adjacent trees. At present, there is no known chemical or fungicide that effectively controls or minimizes the spread of this root-rot disease. The disease is known to remain dormant in the soil for more than 50 years. Silvicultural research shows that red alder (*Alnus rubra* Bong.) is a good inhibitor of *Poria weirii* root rot.

## SURVEY RESEARCH

Remote sensing research in the past has attempted to discriminate previsually (prior to any visible external changes) root-rot-infected Douglas-fir trees from healthy trees. Because of the slow demise of infected trees, foliar characteristics of healthy and diseased trees are so similar that aerial photographic techniques in the visible and near infrared portions of the spectrum (0.34 to 0.95 micrometer) are unable to differentiate affected trees. Some success has been attained with thermal infrared scanning techniques (8.0 to 14.0 micrometer band) operating a nonimaging radiometer from a low-flying helicopter. Temperature differences were relatively small (1° to 3° F.) so that it is highly unlikely that even the most sophisticated sensors (not currently available) could detect individually affected trees from orbiting spacecraft.

The more promising aerial survey technique that has now been discovered identifies root-rot disease centers in certain areas on aerial photographs taken from suborbital altitudes. The technique also has potential for imaging these discrete signatures from orbital altitudes. Openings in the forest canopy have distinctive characteristics that can be frequently identified on aerial photographs and may be exploited by photo interpreters and resource managers.

The major objectives of the *Poria weirii* remote sensing study during the past year were (1) to determine the criteria for detecting root-rot centers or openings, (2) to investigate the distribution of signature indicators on existing photographs covering the Douglas-fir types in Oregon and Washington, (3) to cooperate with various forestry agencies in developing an intensive survey program on selected test sites in Oregon, (4) to determine the optimum photographic scale for detecting infection centers, and (5) to compare various types of multispectral imagery, i.e., color, color infrared, and black-and-white photography, for discriminating disease infection centers or openings from healthy trees.

The primary indicator of *Poria weirii* root rot was discovered in the high Cascade Mountains of Oregon on 1:15,840 scale panchromatic photographs. The signature consists of an unusual phenomenon of bare ground in a half round circular shape surrounded by trees. A small signature (early Poria stage) may be from 100 to 150 feet in diameter and range upward to 700 feet. A conglomerate of openings gives the appearance of a ringworm pattern and may range upward to 3,000 feet. Determining the cause of the openings in the forest canopy involved a multidisciplinary group of scientists and foresters. Openings can be the result of insect or disease activity, unusual geomorphological features such as rock outcrops, or soil and water deficient strips. The team ground checked several openings in different age classes of the Douglas-fir-hemlock type. The preliminary interpretation that the openings were caused by root-rot disease was verified and has been further substantiated by ground surveys of many plots in 1971.

Not all openings in the forest canopy are caused by root-rot disease. Good interpretative judgments are required to identify Poria openings in different parts of the Douglas-fir subregion. The striking appearance of the circular bare ground indicator in the high Cascades of Oregon was the primary criterion for identifying root-rot centers in other forested areas of the Pacific Northwest. In the early stages of development, a Poria signature appears on the aerial photo as a circular opening in the forest stand, or as a "hole," with dead and downed trees jackstrawed in the center and standing trees in various stages of deterioration at the edges of the opening. Stand openings increase radially from the center of infection. Where brush and other vegetative species do not invade the bare areas rapidly the circular bare ground signature is readily discerned. At lower elevations and on better timber sites, small trees (primarily hardwoods) and brush invade rapidly to obscure downed trees and increase the problem of positively identifying root-rot disease centers. Both large and small pockets of bark beetle-killed trees in various stages of deterioration in the forest stand may also confuse interpretation. Considerable field experience is needed by the photo interpreter to delineate root-rot disease-caused openings.

## ESTABLISHING TEST SITES

As a first step in establishing test sites to develop the survey methodology to detect Poria weirii root-rot centers in the Douglas-fir subregion, we needed to know where (based on the general distribution of root-rot signature indicators) tree mortality was in progress. Existing photographs covering approximately 30 million acres on 12 National Forests in Oregon and Washington were carefully scrutinized by two interpreters for the presence or absence of discrete Poria indicators. Interpretations on some 8,200 panchromatic photographs at scales ranging from 1:10,000 to 1:15,840 indicated disease signatures on four National Forests and likely disease signatures on eight others.

From this broad photographic overview of root-rot disease in the Northwest, three test sites were selected (Fig. 2) for more detailed examination, photographic coverage, and analysis. Each test site encompasses 9 square miles (3-mile x 3-mile block) of pole and sawtimber stands. A variety of disease, stand, and climatic conditions, slope and elevations, and forest types were sampled.

1. The Waldo Lake test site (Willamette N. F.) is in the high Cascades of Oregon. It has some brushy areas and moderate to easy terrain accessibility.

2. The Olallie Lake test site (Mt. Hood N. F.) is in the Oregon Cascades. It is brushy with areas of dense reproduction and moderate terrain accessibility.

3. The Divide Lookout test site (Siuslaw N. F.) is in the Coast Range of Oregon. It is brushy with extensive understory of vine maple (*Acer circinatum* Pursh), *Rhododendron* sp., and red alder. It has extremely rough terrain with deeply dissected slopes of 80 to 90 percent.

## INTERAGENCY COOPERATION

Forest resource managers from Federal, State, and private forestry groups have shown a great interest in the new root-rot disease signature. This has stimulated a strong cooperative research and development program to evolve a survey method for detecting and evaluating the impact of root-rot disease on the forest resources of the Northwest. Several Federal and State agencies (listed in the ACKNOWLEDGMENTS section) are contributing manpower and/or financial help to assist in the collection of ground truth and in obtaining aerial photography. This interagency cooperative effort will materially increase the likelihood of gathering extensive and intensive ground truth and of developing a practical airborne survey sensing system in the shortest possible time. A well-developed survey system (orbital or suborbital) can dramatically assist in protecting one of our most valuable natural resources in the Pacific Northwest--our National Forests.

## AERIAL PHOTOGRAPHY

Photographic interpretations of 1967-69 panchromatic photos at the three test sites indicated a wide range of terrain, vegetative conditions, and appearance of suspected root-rot disease openings. A preliminary ground evaluation of the different sites was necessary to determine the feasibility of testing minimum and maximum photographic scales. The vegetative complexity of the Coast Range test site clearly indicated the need for maximum ground detail to delineate root-rot openings. Consequently, photo scales larger than 1:15,840 were considered essential for the initial tests in the Divide Lookout test site of the Coast Range (Fig. 3, 4). Because of the more easily discerned signature indicators in the high Cascades of Oregon (Waldo Lake and Olallie Lake), much smaller scale photography (Fig. 5, 6) (including orbital imagery) may be adequate to detect *Poria weirii* disease centers.

Cooperative efforts of the Remote Sensing Work Unit, Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service; Pest Control, Timber Management Division, Region 6, U. S. Forest Service; and NASA, through the use of their RB-57 aircraft, were to provide photographic coverage (Table III) of the three 9-square-mile test sites with three types of photography and a wide variety of photo scales. Each test site was photographed with Aero color negative film (2445) which provides either color or black-and-white prints and with color infrared film (2443) using a Wratten #15 filter.

The Forest Service used Zeiss 8 1/4" focal length cameras for all film and scale combinations. The multiscale photography was provided by the PSW Forest and Range Experiment Station's Aero Commander and by the U. S. Forest Service Region 6 Cartographic Section's twin Beechcraft. NASA had planned to use two RC-8 cameras (6" and 12" focal lengths) and four 70 mm cameras, 1.57" (40 mm) focal length to 6" focal length (2 1/4" x 2 1/4" format), from an RB-57 or U-2 jet-type aircraft. However, tight scheduling for the NASA aircraft in 1971 prevented the photographic missions anticipated. The photo mission has been rescheduled for NASA aircraft for July 1972.

## COLLECTING GROUND TRUTH

Based on criteria developed during preliminary ground inspection of *Poria weirii* root-rot openings, two photo interpreters scrutinized the available 1:15,840 scale panchromatic photos taken in 1967-69 of each 9-square-mile area selected for the study. Openings and type areas suspected as indicative of root-rot centers were classified into two categories--good *Poria* signatures and possible *Poria* signatures. Each suspect area was circled and numbered on a frosted acetate overlay attached to each photo. Areas of timber that did not appear infected with *Poria* were also marked on the photos to serve as control checks.

From this interpretation data, 75 or more areas on each test site were selected for ground visitation. Areas to be checked were chosen largely on the basis of accessibility. The extremely adverse terrain on the Divide Lookout test site (Siuslaw N. F.) necessitated that plots be within a few chains of a road. Presence or absence of *Poria* root rot was determined by the examination of several living, dead, and downed trees for diagnostic signs of the fungus, including ectotrophic mycelium, setal hyphae, and laminated decay. Check plots were 1/5 acre or more in size and located at least 2 chains from known *Poria* centers. Two 2-man teams under the direction of a trained forest pathologist visited all designated plots on the three test sites in 1971.

## PHOTO INTERPRETATION

Photo interpretation on this study consists of four phases: (1) a comprehensive overview of the Douglas-fir-hemlock timber areas of the Pacific Northwest for Poria root-rot signatures and selecting three test sites, (2) photo interpretation selection of plots for collecting ground truth on each test site, (3) preliminary interpretation of 1971 photography for determining relative accuracy of photo scales for detecting disease centers, and (4) intensive and detailed interpretations of specific plots within each of three selected test sites by five interpreters. Phase one was the interpretation of some 8,200 panchromatic photos covering approximately 30 million acres to detect any type of signature indicators in the forest types of Oregon and Washington that might be caused by a root-rot forest disease and to establish the three test sites.

The second phase was the intensive photo interpretation on 1:15,840 scale black-and-white photographs of the three test sites in Oregon to identify plots for field visitation. The three test sites include indicators ranging from simple to complex. Two experienced photo interpreters received field training on different types of openings in forest areas of the high Cascades and Coast Range before interpreting Poria signatures on photos of the three test sites. More than 75 plots were chosen for field examination in each test site. Good accessibility was the primary concern for final plot selections.

The third interpretation phase developed toward the end of the summer as new photo coverage was obtained on each test site with black-and-white, color, and color infrared photography and at different photo scales. The two most experienced interpreters examined all test site area photos--first on small scale and then progressing to large scale with a random selection from the available film types (Table IV).

Unfortunately, color prints, panchromatic prints, and color IR film were not available for interpreting all photo scales and test sites before the end of the field season so that the results do not show the complete photo interpretation potential.

The fourth and final phase of the photo interpretation for the 1971 photography is in progress. A more detailed analysis of all film-filter and scale combinations is needed to make statistically valid and meaningful comparisons that can be utilized in establishing sound aerial photographic survey procedures.

The large number of plots selected and field checked on each test site provided a sound basis for using a randomized block design with a factorial feature at each of the three test sites. Nine combination treatments are possible at each test site--three types of photography with each of three photo scales. From a total of 72 plots in each test site, eight were randomly selected for each film-scale combination. Each of the 72 plots will be interpreted once by each of five interpreters, thus removing a possible source of interpreter bias. Tests of significance will be performed for film types, photo scales, and the photo-scale film interaction.

## RESULTS AND CONCLUSIONS

An inspection of the preliminary photographic interpretation data (Table IV) shows that larger photo scales did not materially improve accuracy. Relatively small differences in accuracy are indicated between photo scales for each of the high Cascade test sites. It is apparent that a high degree of survey accuracy should be attainable in detecting Poria centers in the Waldo Lake test site area. Somewhat less accuracy is attainable in the Olallie Lake test site area. With sampling techniques currently available, there should be no problem in promulgating a statistically sound aerial photographic survey design such as double sampling with stratification. Further research in remote sensing survey techniques is needed for the forest conditions of the Coast Range.

Even though the signature was first observed in the Pacific Northwest, there is good likelihood that similar characteristic patterns of root-rot diseases should be evident in various forested areas of the United States, Canada, and the world at large. Detecting this type of characteristic signature on photography and relaying this information to forest managers, pathologists, or timber owners will draw attention to distressed areas and help reduce timber losses from forest diseases.

## FUTURE REMOTE SENSING RESEARCH

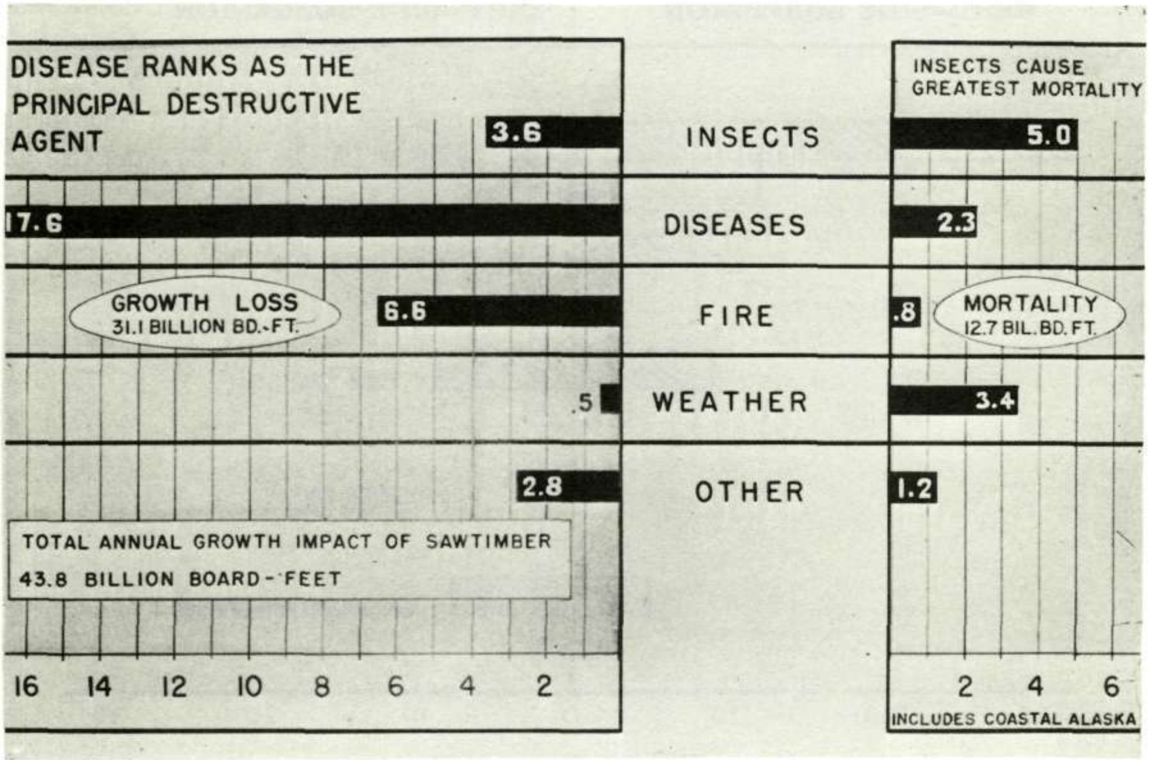
The promising results of the preliminary interpretations in the high Cascades of Oregon are sufficiently encouraging to attempt an aerial photographic trial survey in 1972 to estimate Poria root-rot impact in and adjacent to the Waldo Lake test site. Aerial photography is contemplated for approximately 1,000 square miles using either total coverage at 1:31,680 scale (Fig. 3) or on a sampling basis at 1:15,840 scale.

Because of the relatively large size of root-rot infection centers (100-700 feet singly to 3,000 feet in groups), there is a good possibility that the Earth Resources Technology Satellite (ERTS) imagery may detect the incidence of Poria disease in the forest environment. The three Poria weirii test sites in Oregon are included in the Oregon State University ERTS proposal for 1972. Plans have been made to scrutinize

ERTS imagery of these test sites for Poria centers when it becomes available and to collate the data with suborbital photography taken in 1971.

Aerial photographic support has already been requested from NASA overflights (RB-57 or U-2) in July 1972 for the three Oregon test sites. This photography will simulate orbital and suborbital photo scales not currently available for analysis and improved disease survey methodology. These data should indicate success-ratio likelihood for aerial surveys of forest diseases from both orbital and suborbital altitudes. Analysis of the integrated ERTS and suborbital imagery should corroborate the feasibility of using space platforms for securing valuable information to help forest managers detect and analyze critical forest problems. NASA and the Earth Resources Technology Satellite program can make a substantial contribution to improvement of forest management techniques.

TABLE I. - ANNUAL MORTALITY AND GROWTH LOSSES
TO FOREST RESOURCES IN THE UNITED STATES.*




* Timber Resources for America's Future. Forest Service, U. S. Department of Agriculture, Report No. 14. January 1958. pp. 193.

TABLE II. - ANNUAL TIMBER LOSSES FROM
*PORIA WEIRII* ROOT ROT IN PACIFIC NORTHWEST

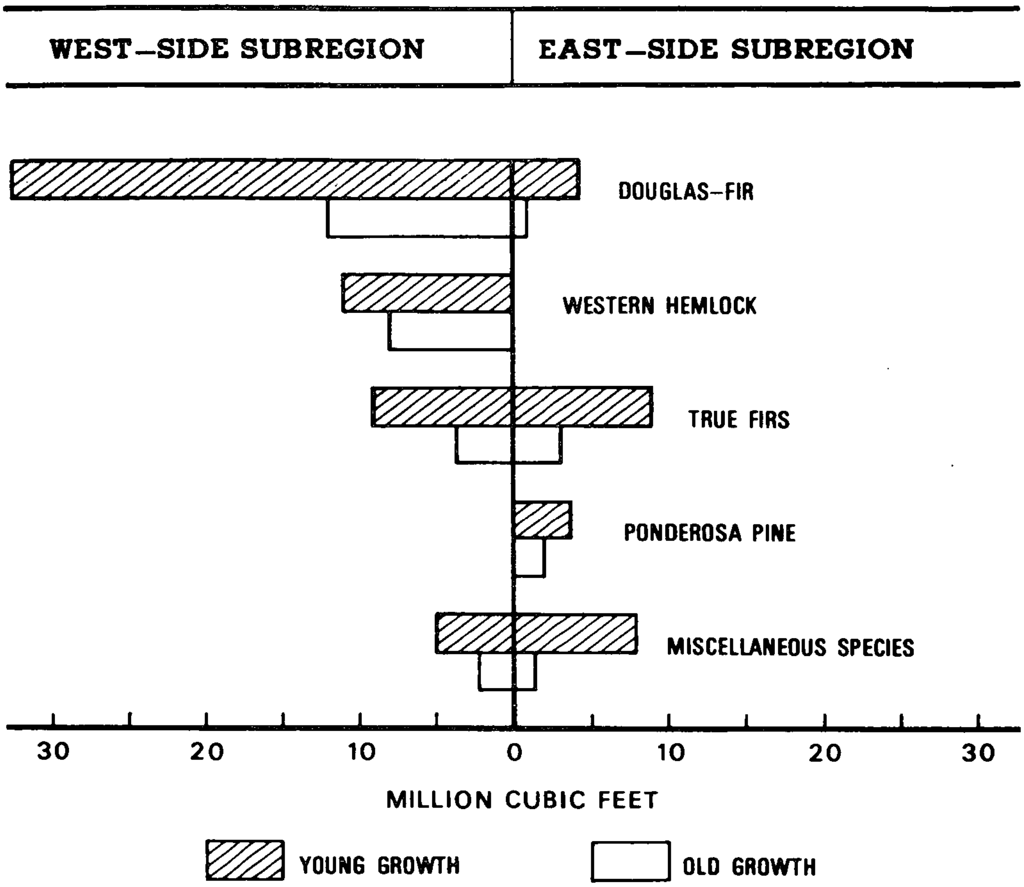


TABLE III. - PORIA ROOT ROT TEST SITES IN OREGON AND PHOTOGRAPHIC SCALES PLANNED FOR 1971

| Divide Lookout (Coast Range) | Waldo Lake (Cascades) | Olallie Lake (Cascades) |
|---|---|---|
| 1:4,000 (USFS) | | |
| 1:8,000 (USFS) | 1:8,000 (USFS) | 1:8,000 (USFS) |
| 1:15,840 (USFS) | 1:15,840 (USFS) | 1:15,840 (USFS) |
| | 1:30,000 (USFS) | 1:30,000 (USFS) |
| | 1:60,000 (NASA) | 1:60,000 (NASA) |
| | 1:125,000 (NASA) | 1:125,000 (NASA) |
| | 1:250,000 (NASA) | 1:250,000 (NASA) |

C 3

TABLE IV. - PHOTO INTERPRETATION ACCURACY IN DETECTING ROOT-ROT DISEASE ON THREE TEST SITES IN OREGON

| Type of Photography | Scale | Waldo Lake | Olallie Lake | Divide L.O. |
|---|---|---|---|---|
| Panchromatic | 1:15,840 | 93% | 80% | 64% |
| Color | 1:31,680 | 87% | 73% | ---* |
| Color | 1:15,840 | ---* | ---* | 61% |
| Color | 1:8,000 | 89% | 76% | 62% |
| Color | 1:4,000 | ---* | ---* | 50% |

* Not included in the photographic coverage

Figure 1.- Ground view of Poria weirii (Murr.) root-rot disease showing disintegrated root system of Douglas-fir trees and downed logs. Infection spreads radially to attack and fell adjacent trees. Detection of root-rot disease centers will help to minimize losses of salvable timber and minimize spread.

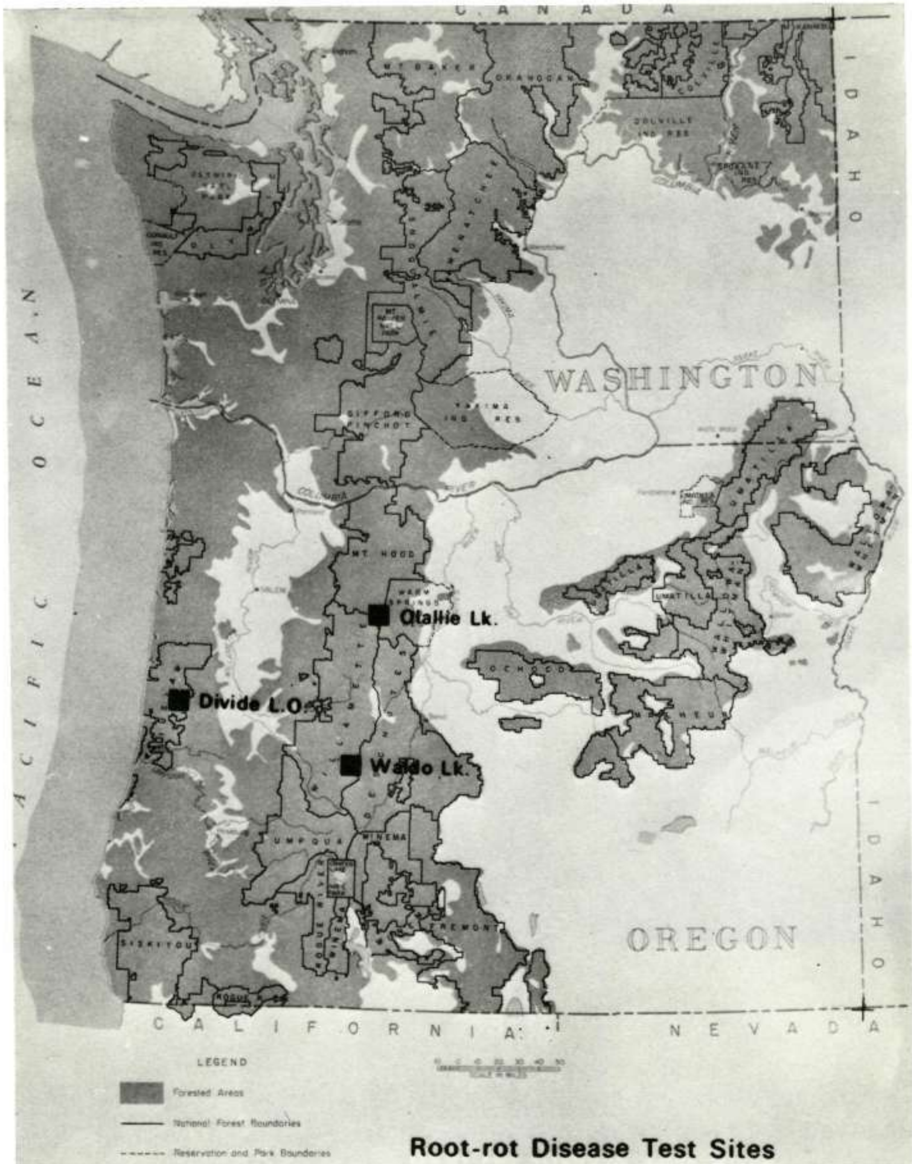



Figure 2.- Map of Oregon and Washington showing distribution of Douglas-fir-hemlock types and location of three test sites--Waldo Lake and Olallie Lake in the high Cascades and Divide Lookout in the Coast Range. Each test site is 9 square miles (3 miles x 3 miles) and covers a variety of vegetation and terrain conditions.

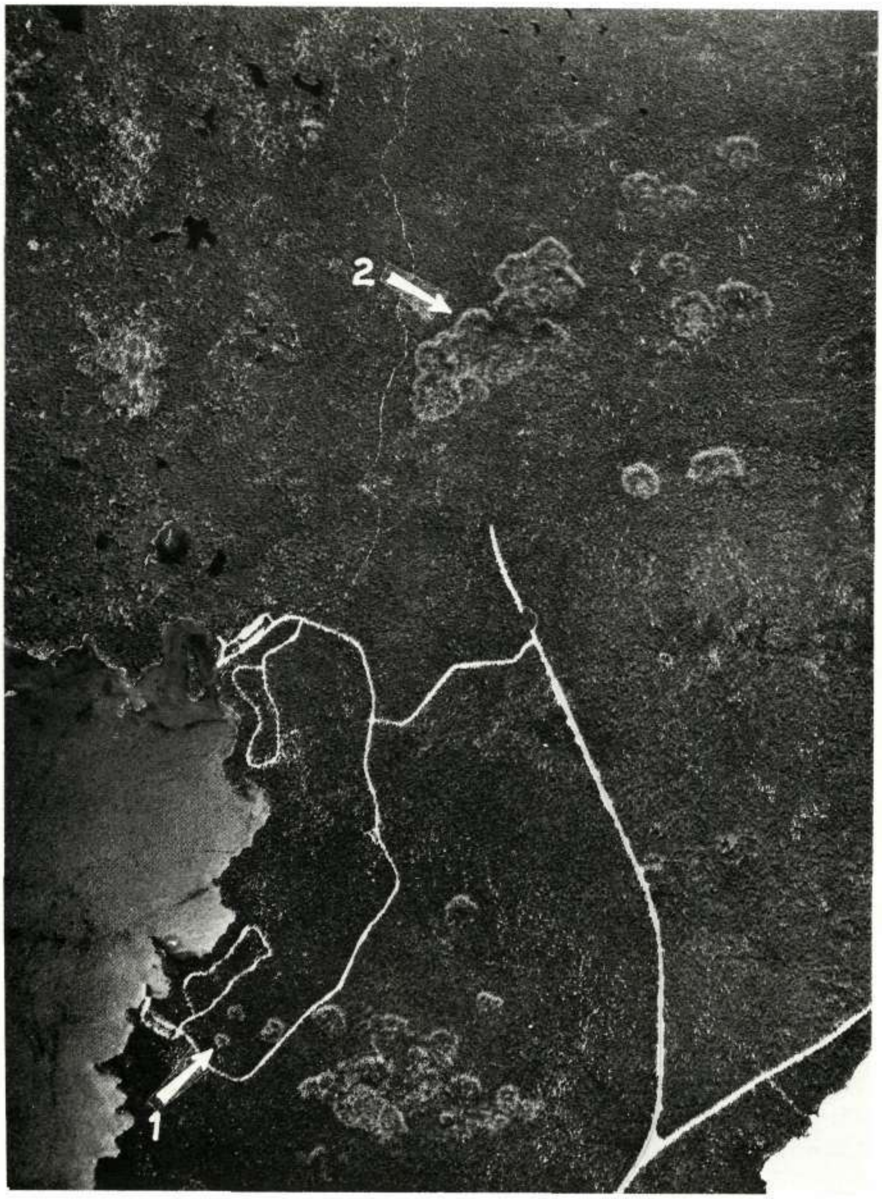



Figure 3.- 1:31,680 scale vertical of Waldo Lake test site showing Poria weirii root-rot signature in high Cascades of Oregon. Note "ringworm" pattern of bare ground openings caused by root-rot disease. Single patterns (1) range from 100 feet to 700 feet in diameter. Coalescing patterns (2) range up to 3,000 feet.

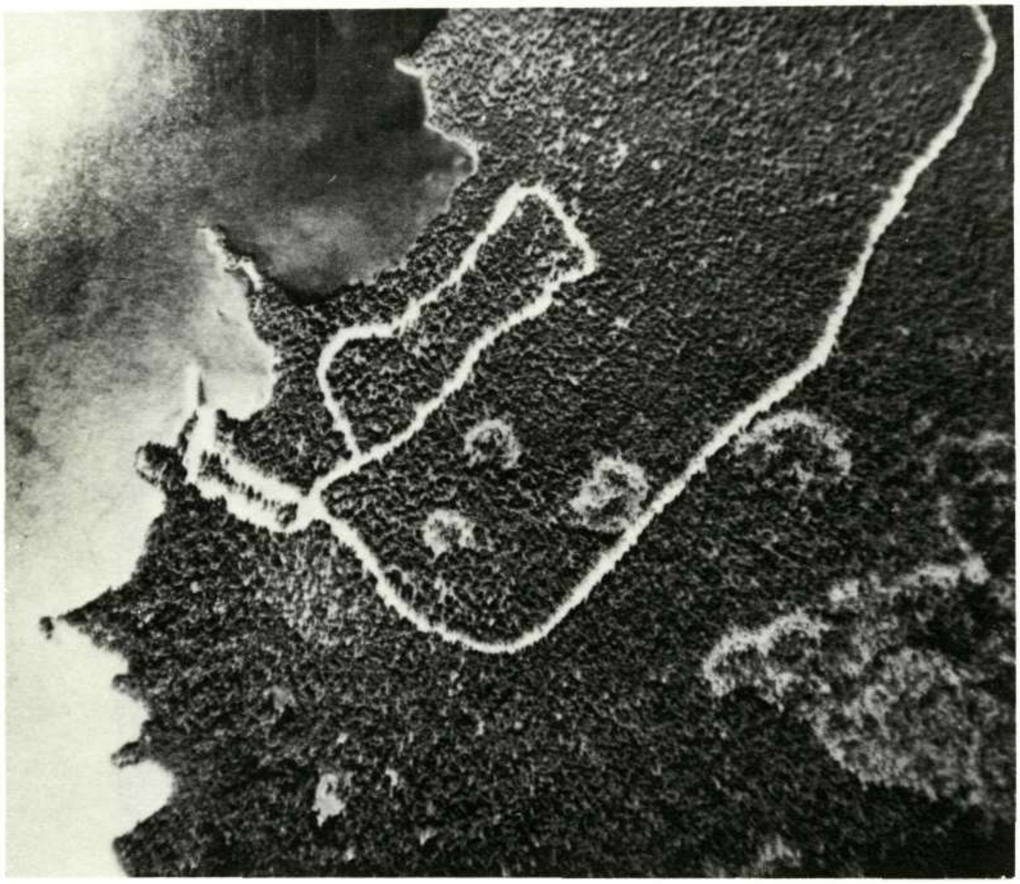


Figure 4.- 1:8,000 scale vertical of Waldo Lake test site showing typical root-rot pattern. Some disease-resistant herbaceous trees and plants are encroaching into the center of the openings but will eventually succumb to the root rot.

Figure 5.- 1:15,840 scale oblique of the Divide Lookout test site shows land-use pattern, periodic logging, Poria centers, and steepness of terrain (80 to 90% slopes).

Figure 6.- 1:4,000 scale oblique of the Divide Lookout test site shows Poria center below lookout. Some standing dead trees around edges of the opening and some downed logs are visible. Brush and hardwood species are rapidly filling in the openings.

## ACKNOWLEDGMENTS

I wish to acknowledge the following agencies who have contributed manpower and/or financial assistance in conducting these studies:

Insect and Disease Control, Timber Management, Pacific Northwest Regional Office, Region 6, Forest Service, U. S. Department of Agriculture.

Forest Disease Research, Pacific Northwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture.

Remote Sensing Work Unit, Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture.

Earth Resources Survey Program, National Aeronautics and Space Administration.

Oregon State Board of Forestry.

N72-29415



SECTION 123

# PATTERN RECOGNITION OF NATIVE PLANT COMMUNITIES--

# MANITOU COLORADO TEST SITE



by

Richard S. Driscoll[1/]
Rocky Mountain Forest and Range Experiment Station
U.S.D.A. Forest Service, Fort Collins, Colorado

## ABSTRACT

Optimum channel selection among 12 channels of multispectral scanner imagery identified six as providing the best information about 11 vegetation classes and two nonvegetation classes at the Manitou Experimental Forest (NASA Test Site 242). Intensive preprocessing of the scanner signals was required to eliminate a serious scan angle effect. Final processing of the normalized data provided acceptable recognition results of generalized plant community types. Serious errors occurred with attempts to classify specific community types within upland grassland areas. The consideration of the convex mixtures concept--effects of amounts of live plant cover, exposed soil, and plant litter cover on apparent scene radiances--significantly improved the classification of some of the grassland classes. The data processed was obtained as part of Mission 19 at 1000 hours on July 29, 1970, by the University of Michigan multispectral scanner flown at 915 meters (3,000 feet) above mean terrain elevation.

## INTRODUCTION

Multispectral scanner imagery coupled with automation data processing may well be the future technique for classifying nonagricultural vegetation or especially monitoring changes in this vegetation. The scanner "looks" at a piece of landscape, the area depending on the resolution of the system, and records the

---

1/ Project Leader and Principal Plant Ecologist in charge of Remote Sensing Research.

data on magnetic tape for analyses. During the analysis process, the computer makes yes-no decisions to align the spectral radiances recorded for the resolution elements to predefined categories. Thus, bias and variances adherent to aerial photographs and photo-interpreters, including differences among interpreters and variances in photo quality, may be circumvented.

For monitoring vegetation, plant species or groupings should maintain similar radiances provided physical and physiological factors are relatively constant (Knipling 1970). Physiological changes in the plant species will cause radiance changes of the species (Gausman, Allen and Cardenas 1969; Weber and Olson 1967). Structural changes in the plant community, which varies the geometry of the grouping, also changes the radiance of the community (Allen and Richardson 1968). For a given area of landscape therefore, changes in the scene caused by a disturbance of the vegetation should result in different scene radiances and these data would be used to assess change in vegetation over time. Frequently, these changes are subtle and important to land management decisions, but may not be read from aerial photographs or observed on the ground.

The problem of the effects of variable atmospheric paths on spectral signals obtained by remote sensors in the optical region of the spectrum and how to cope with them have been documented (Horvath, Braithwaite and Polcyn 1970). These data could be interfaced with raw multispectral scanner data so that processing the latter deals with absolute and not relative values.

Before we can use these inferences, dependable evaluations must be made on the level of integrity with which multispectral scanning systems discriminate dissimilar plant communities. The research reported here are some of the most significant results of an experiment to test the hypothesis that multispectral imagery will identify specific plant communities determined by ecological analyses.

## DATA ACQUISITION

### THE STUDY AREA

The study area for this research is located approximately 25 airline miles northwest of Colorado Springs, Colorado, and is within the Manitou Experimental Forest. The Forest is a 16,000-acre area within the ponderosa pine/bunchgrass type where scientists at the Rocky Mountain Forest and Range Experiment Station are involved in multidisciplinary wildland research. The vegetation is typical of much of the lower Montane Zone along the eastern slope of the Rockies; open to dense stands of ponderosa pine (Pinus ponderosa, Laws.) are interspersed with meadows and grassland parks.

The specific test site included an area approximately 7.28 square kilometers (2.81 square miles) with a mean ground datum of 2,350 meters (7,700 feet) (Fig. 1). Within the area were three general kinds of vegetation: (1) Ponderosa pine forest, (2) upland grasslands which included native and seeded grass stands, and (3) hydrophyllic communities.

## GROUND DATA

Detailed mapping of plant communities was completed immediately prior to the scanner mission. This was based on current aspection of the plant communities and the relative composition of the communities regarding similarity of plant species components. Medium scale (1:8000) color infrared mapping photographs flown approximately 6 weeks prior to the scanner mission were used in conjunction with detailed ground search. At this photo scale, each mapping unit represented a specific community type.

Plant species abundance was determined for each community type within 2 weeks of the mission. Abundance was based on a 5-point rating scheme ordered from very abundant to rare (Oosting 1956). At the same time, percent plant foliar cover, percent bare soil surface, and percent plant litter cover of the soil surface (the sum of the three equalling 100 percent viewed vertically) was estimated. This was done by sampling with 9- X 9-foot sample plots (Fig. 2) located by restricted random fashion throughout each community type. This plot size related to the equivalent resolution element to be "seen" by the scanner at the planned flight altitude to represent scene radiance of the element component mixtures.

Ground cover sampling in the forest communities was restricted to land surface visible from above without interference from the tree canopy. All ground data were obtained during late July and early August, the time when most plant species were actively growing. The mapping units, which corresponded to recognition categories of the scanner data, and a brief description of their characteristics are listed in Table 1. Also included are two nonvegetation categories

AC

which were inclusions in the mapping units but which could possibly be discriminated in the multispectral analyses.

## AERIAL DATA

All multispectral data collection was performed by the University of Michigan's multispectral scanning system. This system consisted of two double-ended optical mechanical scanners. Imagery included data records in 12 discrete spectrometer channels in the visible and near infrared regions of the spectrum (Table 2).

The scanner was flown at approximately 305 meters (1,000 feet) and 915 meters (3,000 feet) above ground datum on July 28 and 29, 1970. Four time periods were selected: 0830, 1200 and 1600 hours local sun time on July 28, and 1000 hours on July 29. Only the data obtained at the last time period at the 915 meter (3,000 feet) altitude was used for subsequent analyses. This time and altitude were selected for four primary reasons: (1) weather at the time of the overflight was clear with visibility in excess of 160 kilometers (100 miles), (2) video display of preprocessed data from channel 10 (.604 - .700 micrometers) indicated this information might provide the best opportunity for recognition processing, (3) environmental conditions during the 0830 flight, heavy predawn rain which left the target surfaces wet, and the 1200 and 1600 flights, during which cloud shadows were in the imaged areas, would produce false radiance signals, and (4) the "halo" effect in the imagery caused by the airplane shadow in the 1200 and 1600 flights which would cause data processing problems for removing the effect.

## RESULTS AND DISCUSSION

### PREPROCESSING

Conventional techniques for analyzing multispectral data for classification and mapping terrain features assume uniform apparent radiance in each class regardless of position in the scene. Previous studies have shown that this is not true because such things as atmospheric haze, variations in topography, scanner look angle, and variations in geometry of the scene to be classified all affect the apparent scene radiance (Solomonson and Marlatt 1971; Smedes et al. 1970). The scan angle effect should be expected since the look angle of the scanner mission system for a discrete bit of data about a specified target varies through the arc of the scanner field of view. If this were the only factor affecting the apparent scene radiance, the data could be simply normalized since the strongest point of illumination would be at the nadir, tailing off to each end of the scan line to produce a normal distribution curve.

The previously described condition would seldom occur since the probability of scanner look angle being simultaneously perpendicular to the illumination source (the sun) and the target scene (a plant community of constant geometry) is nil. Therefore, the scan angle effect in relation to apparent scene radiance is influenced by atmospheric effects and bidirectional effects. Atmospheric effects were deemed negligible for this study since visibility was in excess of 160 kilometers and flight altitude was only 915 meters (3,000 feet) above the terrain.

Bidirectional reflectance effects are common and the data from this study were analyzed assuming such effects were present. These effects are the combined result of variation in sun angle, the bidirectional reflectance properties of the target scene caused by varying surface geometry, and scanner look angle. The fact that bidirectional/scan angle effects were present in the data was identified by a technique developed by Kreigler (1971). Figure 3 illustrates this effect from data plotted from channel 5 for three recognition categories. Each point on the curve represents the statistical mean value of a training set consisting of a block of approximately 100 resolution data cells.

This scan angle effect was eliminated from the data using transformation processes developed by Kreigler, et al. (1969). Figure 5 illustrates the results of normalizing the channel 5 data for the three example categories.

## RECOGNITION PROCESSING

Signature Selection.- Signature selection to represent recognition categories (Table 1) was relatively simple using the preprocessed data provided the selected training sets were relatively homogeneous. This was true for recognition categories 14, 16, and 17 (see Table 1 for explanation of categories). Since the location and spacial distribution of these units was quite limited and homogeneous, the spectral signature to represent each category was a single training set obtained directly from the data. More than one training set was used to determine the statistical spectral signature for categories 2, 3, 4, 12, and 15 (see Table 1 for explanation of categories). However, the computed signature for each category was so similar to any one of the training sets for each category, it was arbitrary as to which one was used. Consequently, only one training area was chosen and its signature extracted directly from the data for all categories except category 2. Since this category was widely distributed throughout the area, information from two training sets were extracted from the data and used to determine a new recognition signature.

The process to obtain a representative signature for the upland grassland categories, units 5 through 9 (see Table 1 for explanation of categories), was much more tedious. Even after the data had been preprocessed, there was wide variation within and among category training set signature values. This was related to two factors: (1) the inability to precisely locate a representative position for a specific training set area for a specific category due to ectonal variation among the categories, and (2) the varying amounts and kind of herbage cover, plant litter, and bare soil represented in the equivalent resolution element. It was difficult to discern boundaries among the grassland units in the gray map generated from preprocessed data in relation to ground control from the mapping photographs. In addition, there was considerable variation in the amounts of ground cover characteristics in ground sample plots, corresponding to the equivalent resolution element, within the originally mapped units although the data were adequate to describe the units on the ground.

Final signature selection for these upland grassland categories was based on a method which used the average probabilities of misclassification as criteria to determine similarity among units. The routine simultaneously considered statistical parameters (mean, variance, and covariance) for all channels of data to compute pairwise probabilities of misclassification. It involved testing distributions by a likelihood ratio test in which each distribution was tested pairwise with all other distributions. The recognized signature for that training set to be used for the spectral signature was that one with a probability density function greater than the probability density functions for all other training sets within the category. The relative location of training sets selected for final recognition processing are shown in Figure 5.

Optimum Channel Selection.- It was expected that not all channels of spectrometer data would be needed to classify the plant communities defined. Therefore, channel optimization was performed to determine the best set of channels to be used. This was based on the average probability of misclassification in which a number of channels were chosen in an ordered selection scheme.

The process assumed that the spectral signatures represented a Gaussian distribution of random variables, an assumption which thus far has been good for similar data (Heller, et al. 1970). A pairwise classification scheme was used in which if there were M categories (recognition units), then there were MCM-1 probabilities of misclassification. For example, the probability of misclassification of each pair of categories was the probability of misclassifying category M2 as category M1. The end result, with weighted entries, provided an average pairwise probability of misclassification and identified the best channel for classifying the vegetation classes previously defined. This ordered selection next combined the first channel with each of the remaining n-1 channels and picked the best combination of two channels. The results of the ordered selection scheme to determine the spectral channels to use for final recognition processing is shown in Table 3.

Six channels were selected for final recognition processing. The channel selection scheme was stopped at this number because addition of data from other channels indicated minimum improvement in recognition accuracy. For example, adding channel 6 data indicated an increase in classification accuracy by only approximately 11 percent. This was deemed acceptable for this problem.

Final Processing.- The decision rule to classify each data point using a likelihood ratio test was used for final processing. The test simultaneously compared the information content of each data point for category recognition and assigned the data point to a particular category when the following n-1 ratio tests were simultaneously satisfied:

$$\frac{f(M_i)}{f(M_j)} > 1$$

where:

$f(M_i)$ is the multivariate Gaussian probability density function for category $M_i$, and

$f(M_j)$ is the multivariate Gaussian probability density function for category $M_j$

The recognition processing produced a digital recognition map (Fig. 6). This area represents a unit of terrain approximately 7.28 square kilometers (2.81 square miles) in area. The color/symbol coding which was used is listed in Table 4. The exact coding is not recognizable in the photography due to scale reduction from the original digital color map. However, if the reader makes a correspondence between color shades and the location of training areas (Fig. 5), this will aid in interpreting the map.

Generalized plant communities were acceptably isolated. These included the forested areas (green), areas with hydrophyllic vegetation (black), and areas of upland herbaceous vegetation (red, blue, and purple). This was expected, however, since others have reported similar results (Smedes, et al. 1971; Heller, et al. 1970). Ground conditions of these units were very dissimilar which produced high contrast in apparent radiance signals.

However, problems existed for classifying the upland herbaceous plant communities (categories 5-9). Even though intense preprocessing of the data was done, a large amount of misclassification occurred. For example, the bluegrass seeding in the northwest portion of the area was synonymously identified with category 8 (abandoned fields with native vegetation) and with parts of category 7 (native range). Likewise, the native range and abandoned fields categories were mixed, severely in some areas.

Due to severe mixing of the bluegrass seedings with other upland grassland categories in the northeast portion of the area, additional processing was done to improve recognition of this unit. The unit was separated into two additional categories. One, category 6-1, represented an old seeding contaminated with yellow sweetclover (*Melilotus officianalis* (L.) Lam.) and the other, category 6-2, represented an old seeding contaminated with numerous native herbaceous species. Reprocessing by extracting spectral signatures for these categories from the data resulted in improved recognition of them. This verifies that community species composition as well as amounts of the three ground cover components are important characteristics to consider for analyses and recognition processing of multispectral scanner data for plant community classification.

It was not possible to follow this procedure with the other upland grassland communities where severe mixing occurred in the recognition processing. The ground control plan did not allow future location of specific areas either on the ground or in various kinds of imagery the exact position where the control data was obtained. Even with the severe mixing of these categories, it does not mean that multispectral scanner data cannot be used for identifying and classifying specific plant community types within a generalized herbaceous system. Rather, it means that more discrete selection must be done of training sample areas to represent the community types relevant to specific ground control. For example, the native range (category 7) areas identified by the recognition processing were correctly identified, but not all native range areas were classified as native range. Those areas correctly identified consisted of plant communities with a composition primarily of vigorous stands of Arizona fescue and mountain muhly and little bare soil surface showing through the community canopy. Other areas not classified as native range but mixed with category 8 (abandoned fields) had considerably less herbaceous cover, less litter cover on the ground and more exposed bare soil surface. Similar conditions existed between the relatively pure big bluegrass seeding in the northwest corner of the area and the more sparsely vegetated native range areas.

It may be that the relative radiance of herbaceous vegetation is not sufficiently contrasting to provide discrete separation of community types within the general system. If this is the case, more consideration must be given to the combined relative amounts of vegetation cover, litter cover, and bare soil surface which may provide the information needed for acceptable multispectral recognition processing. Controlled experiments need to be initiated whereby the effective ground resolution elements can be isolated in the multispectral data for absolute information about the three ground cover characteristics. Also more information is needed about the ground scene radiance of various combinations of ground cover characteristics to determine the effects of these characteristics on effective scene radiance.

The normalized data from the six channels identified for digital processing was also processed through the Michigan Spectral Processing and Recognition Computer. The SPARC system accepts analog data and presents the results as a color map in analog form. Since the SPARC system can accept data about only eight recognition categories and we processed 14 recognition categories using six data channels, two separate operations were performed on the SPARC. The results of this processing are illustrated in Figure 7. The color codes are identified in Table 5.

There was some confusion interpreting the SPARC map as compared to the digital map. For example, the SPARC seeded crested wheatgrass is identified as yellow and the other seeded grassland (category 9) is identified as dark green. Interpreting the digital map point by point shows some mixing of these two categories in the crested wheatgrass area, but the major portion of the data points, in fact, represent the crested wheatgrass area. The SPARC map identifies this area primarily as other seeded grassland. The reason for this crossover is not known now, but available evidence indicates interpretation of the digital map may provide more discrete data about the individual plant community types. A similar relationship existed in SPARC classification of category 6-2 and category 7. Many small areas in the south of the SPARC map were classified as category 6-2 when they should have been category 7. The digital map again identified a mixing of these two categories in the area but the major portion of the data points identified as native range (category 7).

The utility of developing a multispectral processing technique for native vegetation should be obvious. An important concern about management of native vegetation relates to change in vegetation over time and determining what caused the change. Since the multispectral scanner and peripheral equipment records and stores bits of information about a small piece of landscape, depending on the resolution capabilities of the scanner system, any change in that piece of landscape theoretically would be identified by a change in apparent scene radiance in subsequent scanner data. This assumes that discrete limits of the information stored, that is the mean relative radiance levels with variance that are discrete for specific plant communities, can be identified. The percentage of data points representing a kind of plant community can be computed (Table 6) and any change in these relative values can be determined using sequential imagery. This would then represent a change in area comprising a specific community type. Theoretically, this technique would provide more accurate information than photointerpretation only since interpreter error would be minimized. The concept needs substantial additional research to identify the minimum level of integrity the recognition processing can classify plant communities and then tested over time to determine the repeatability of the technique.

## SUMMARY AND CONCLUSIONS

1. Serious scan-angle effects were identified in multispectral scanner imagery taken at 1000 hours on July 29, 1970, at the Manitou Colorado Test Site, by the University of Michigan's multispectral scanner system. The effect was believed to have been caused by bidirectional reflectance which is the combined effect of variation in sun angle, scanner look angle, and the reflectance properties of the specific scene. Atmospheric attenuation was believed not to be a serious influence on the scanner data since visibility was in excess of 160 kilometers (100 miles) at the time of the data mission and the

flight altitude was only 915 meters (3,000 feet) above the terrain.

2. Preprocessing was performed on the data to remove the scan angle effect using techniques developed by University of Michigan IROL research engineers. Theoretically, with the scan angle effect removed, only one computer training sample per recognition category is required for further recognition processing.

Channel optimization for recognizing 11 vegetation and two nonvegetation categories representing mapping units was based on the average probability of misclassification in which the six best channels were chosen on an ordered selection scheme. These were:

| Channel No. | Spectral Band (μm) |
|---|---|
| 10 | 0.604-0.700 |
| 12 | 0.725-0.920 |
| 5 | 0.478-0.508 |
| 9 | 0.566-0.638 |
| 7 | 0.514-0.558 |
| 6 | 0.492-0.536 |

4. The recognition processing results provided acceptable discrimination of generalized plant communities. These included: (1) ponderosa pine forested areas, (2) upland herbaceous vegetation, (3) hydrophyllic herbaceous vegetation. Two nonvegetation categories, asphalt roads and bare soil, were acceptably classified.

5. Serious problems exist in classification of upland herbaceous community systems. Seeded crested wheatgrass was satisfactorily classified. However, seeded big bluegrass was mixed seriously with native range which was in turn confused in the computer processing for abandoned fields with native vegetation significantly different from native range.

6. The classification of upland herbaceous plant communities could be surmounted by considering more carefully the convex mixtures concept. The concept relates to the influence of relative amounts of plant foliar cover, bare soil, and dead plant litter on the soil surface on the apparent radiance levels of the mixtures. In addition, species components of the plant communities, especially the amounts

of grass versus other herbaceous vegetation, need to be more seriously considered in relation to multispectral recognition processing for plant community classification.

## ACKNOWLEDGEMENTS

Special appreciation is extended to the Willow Run Laboratories, University of Michigan, for collecting and processing the multispectral scanner imagery. Specifically, Research Engineers M. M. Spencer, F. J. Kneigler, F. J. Thompson, and P. G. Hassell provided substantial contributions to this research.

## LITERATURE CITED

1. Knipling, E. B. 1970. Physical and physiological basis for the reflectance of visible and near-infrared radiation from vegetation. Remote Sensing of Environment 1:155-159.

2. Gausman, H. W., W. A. Allen, and R. Cardenas. 1969. Reflectance of cotten leaves and their structure. Remote Sensing of Environment 1:19-22.

3. Weber, F. C., and C. E. Olson. 1967. Remote sensing implications of changes in physiologic structure and function of tree seedlings under moisture stress. Annual Progress Report, National Resources Program, National Aeronautics and Space Administration.

4. Allen, W. A., and A. J. Richardson. 1968. Interactions of light with a plant canopy. J. Opt. Soc. Amer. 59:1376-1379.

5. Horvath, R. J., J. G. Braithwaite, and F. C. Polcyn. 1970. Effects of atmospheric path on airborne multispectral sensors. Remote Sensing of Environment 1:203-215.

6. Oosting, H. J. 1956. The study of plant communities; an introduction to plant ecology. 2nd edition. San Francisco, W. H. Freeman. 440 p.

7. Solomonson, V. V., and W. E. Marlatt. 1971. Airborne measurements of reflected solar radiation. Remote Sensing of Environment 2:1-8.

8. Smedes, H. W., K. L. Pierce, M. G. Tanguay, and R. M. Hoffer. 1970. Digital computer terrain mapping from multispectral data. J. Spacecraft and Rockets 7:1025-1031.

9. Kreigler, F. J. 1971. Implicit determination of multispectral scanner data variation over extended areas. In Proceedings, Seventh International Symposium on Remote Sensing of Environment. Ann Arbor, Mich. Vol. I:759-777.

10. Kreigler, F. J., W. A. Malila, R. F. Nalepka, and W. Richardson. 1969. Preprocessing transformations and their effects on multispectral recognition. In Proceedings, Sixth International Symposium on Remote Sensing of Environment. Ann Arbor, Mich. Vol. I:97-131.

11. Smedes, H. W., M. M. Spencer, and F. J. Thompson. 1971. Preprocessing of multispectral data and simulations of ERTS data channels to make computer terrain maps of a Yellowstone National Park Test Site. In Proceedings, Seventh International Symposium on Remote Sensing of Environment. Ann Arbor, Mich. Vol. III:2073-2094.

TABLE 1.- GENERALIZED DESCRIPTION OF VEGETATION

MAPPING UNITS AND NONVEGETATION INCLUSIONS (RECOGNITION CATEGORIES)[1/]

| Mapping Unit (Recog. Cat.) | Description | Ground Surface Characteristics | | |
|---|---|---|---|---|
| | | Plant Foliage | Plant Litter | Bare Soil |
| | | ---------Percent--------- | | |
| 2T | Ponderosa pine forest; vegetation of forest floor mainly mountain muhley (*Muhlenbergia montana* (Nutt.) Hitch.), Arizona fescue (*Festuca arizonica* Vasey) and pussytoes (*Antennaria* sp. Gaertn.). | 38.7 | 54.0 | 11.3 |
| 3 | Dense natural ponderosa pine regeneration; crown closure nearly 80 percent; forest floor primarily pine needle litter | 8.0 | 91.0 | 1.0 |
| 4 | Dense planted ponderosa pine; crown closure nearly 80 percent; herbaceous understory primarily mountain muhley | 31.2 | 57.7 | 11.1 |
| 5 | Seeded crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.) grassland | 27.7 | 51.4 | 20.9 |
| 6 | Seeded big bluegrass (*Poa ampla* Merr.) grassland | 19.2 | 72.4 | 8.4 |
| 7 | Native grasslands; no tree or shrub components; Arizona fescue and mountain muhley most conspicuous species; other herbaceous species more prominent locally | 36.5 | 58.4 | 5.1 |
| 8 | Abandoned agricultural fields; land once tilled but native vegetation different from Unit 7 reestablished, primarily lacking in variety and abundance of perennial forbs | 41.9 | 49.1 | 9.0 |

RD

TABLE 1. (Cont.)

| Mapping Unit (Recog. Cat.) | Description | Ground Surface Characteristics | | |
|---|---|---|---|---|
| | | Plant Foliage | Plant Litter | Bare Soil |
| | | ---------Percent--------- | | |
| 9 | Other seeded grasslands; old seedings of crested wheatgrass, big bluegrass, and Russian wildrye (Elymus junceus Fisch.) which have been infested with native herbaceous species | 31.7 | 46.6 | 21.7 |
| 12 | Willow (Salix sp. L.) occurring along the flood plain of a stream; herbaceous species occurring within open areas between shrub groups either Unit 14 or 15 | 98.0 | 1.0 | 1.0 |
| 14 | Native bluegrass (Poa praetensis L.); species of sedge (Carex sp. L.), rush (Juncus sp. L.) and native clover (Trifolium sp. L.) ubiquitously scattered throughout the area | 85.0 | 12.7 | 2.5 |
| 15 | Sedge/rush/bulrush (Scirpus sp. L.) meadows; normally occurring with standing water or in seasonally ponded areas | 94.7 | 5.3 | 0 |
| 16 | Asphalt roads | 0 | 0 | 0 |
| 17 | Bare soil; aluvial fans, unstable gullies, road cuts and fills | 0 | 0 | 0 |

1/ Not all categories are included since they either did not occur in the area or were not used for this study.

TABLE 2.- SPECTROMETER CHANNELS AND WAVELENGTHS USED FOR TARGET RECOGNITION BY THE UNIVERSITY OF MICHIGAN AIRBORNE SCANNER SYSTEM

| Spectrometer Channel No. | Wavelength (micrometers) |
|---|---|
| 1 | .398-.431 |
| 2 | .423-.456 |
| 3 | .446-.475 |
| 4 | .458-.487 |
| 5 | .478-.508 |
| 6 | .492-.536 |
| 7 | .514-.558 |
| 8 | .538-.593 |
| 9 | .566-.638 |
| 10 | .604-.700 |
| 11 | .656-.775 |
| 12 | .725-.920 |

TABLE 3.- SPECTRAL CHANNELS ORDERED FOR CLASSIFICATION OF SEVEN HERBACEOUS PLANT COMMUNITIES, THREE PONDEROSA PINE FOREST COMMUNITIES, ONE SHRUB COMMUNITY, AND TWO NONVEGETATED CATEGORIES

| Spectrometer Channel No. | Spectral Band (micrometers) | APPM 1/ | Percent Accuracy Increase |
|---|---|---|---|
| 10 | 0.604-0.700 | 0.0736 | |
| 12 | 0.725-0.920 | 0.0386 | 48 |
| 5 | 0.478-0.508 | 0.0290 | 25 |
| 9 | 0.566-0.638 | 0.0240 | 17 |
| 7 | 0.514-0.558 | 0.0209 | 13 |
| 6 | 0.492-0.536 | 0.0185 | 11 |

1/ Average pairwise probability of misclassification

TABLE 4.- COLOR/SYMBOL CODES FOR DIGITAL COLOR RECOGNITION MAP

| Category[1/] | Unit | Color | | | | |
|---|---|---|---|---|---|---|
| | | Green | Red | Blue | Black | Purple |
| 2T | Ponderosa pine forest | Ø | | | | |
| 3 | Natural pine regeneration | Θ | | | | |
| 4 | Artificial pine regeneration | * | | | | |
| 5 | Crested wheatgrass seeding | | | Ø | | |
| 6-1 | Seeded big bluegrass with sweet-clover | | * | | | |
| 6-2 | Seeded big bluegrass with conglomerate forbs | | | * | | |
| 7 | Native range | | | | | 6 |
| 8 | Abandoned fields different from #7 | | Ø | | | |
| 9 | Other seeded rangeland | | | = | | |
| 12 | Willow communities | | | | Ø | |
| 14 | Native bluegrass meadows | | | | * | |
| 15 | Sedge/rush/bulrush meadows | = | | | | |
| 16 | Road (Asphalt) | | | | . | |
| 17 | Bare soil | | = | | | |
| Not Classified | | Blank spots in the map | | | | |

1/ Category 6 was separated into two units in the southeast portion of the area due to severe mixing with other categories, especially #9. 6-1 now represents big bluegrass seeding contaminated with yellow sweetclover (*Melilotus officinalis*); 6-2 represents big bluegrass seeding contaminated with numerous other herbaceous species.

TABLE 5.- COLOR CODING FOR SPARC RECOGNITION MAP FOR FIGURES 7(a) AND 7(b)

| Figure 7(a) | | | Figure 7(b) | | |
|---|---|---|---|---|---|
| Category | Unit | Color | Category | Unit | Color |
| 2T, 3, 4 | All ponderosa pine | Green | 6-1 | Seeded big bluegrass with sweetclover | Dark Blue |
| 12 | Willow communities | Orange | 6-2 | Seeded big bluegrass with conglomerate forbs | Light Blue |
| 14 | Native bluegrass meadows | Purple | 12 | Willow communities | Orange |
| 6-1 | Seeded big bluegrass with sweetclover | Dark Blue | 9 | Other seeded rangeland | Dark Green |
| 15 | Sedge/rush/bulrush meadow | Red | 5 | Crested wheatgrass seeding | Yellow |
| | | | 8 | Abandoned fields with vegetation different from | Red |
| | | | 7 | Native rangeland | Purple |
| | | | 17 | Bare soil | Black |

TABLE 6.- PERCENTAGE AND NUMBER OF DIGITIZED IMAGERY POINTS RECOGNIZED ACCORDING TO CATEGORY FROM THE DIGITAL RECOGNITION PROCESSING

| Category | | Percentage of Points | Number of Points |
|---|---|---|---|
| 2T | | 19.8 | 45,099 |
| 3 | | 13.3 | 30,294 |
| 4 | | 9.6 | 21,866 |
| 5 | | 2.0 | 4,555 |
| 6-1 | | 4.7 | 10,705 |
| 6-2 | | 5.0 | 11,389 |
| 7 | | 9.2 | 20,955 |
| 8 | | 13.4 | 30,521 |
| 9 | | 2.9 | 6,605 |
| 12 | | 2.6 | 5,922 |
| 14 | | 1.0 | 2,278 |
| 15 | | 1.2 | 2,733 |
| 16 | | 1.2 | 2,733 |
| 17 | | 0.6 | 1,367 |
| Not Recognized | | 13.5 | 30,749 |
| | Totals | 100.0 | 227,772 |


Figure 1. - Aerial view (scale 1:53,000) of the study area within the Manitou test site. Three general kinds of vegetation are easily discerned: (a) ponderosa pine forest, (b) upland grasslands, and (c) hydrophyllic communities. Stereo-interpretation and ground search provided ecological classifications of three forest types, five upland grassland types, and three hydrophyllic types.

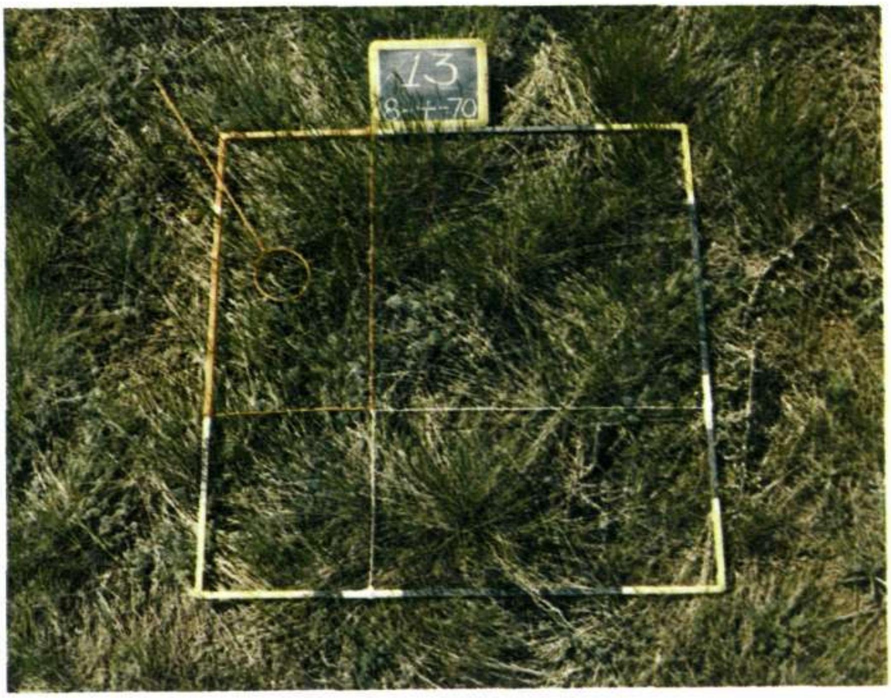



Figure 2.- Three-foot (0.91 meter) square plots were used to obtain estimates of percent foliar cover, bare soil surface, and plant litter cover from a series of 7.5 square meter (81 square foot) plot areas within each plant community. The 81 square foot areas represented the equivalent resolution element scene for the 915 meter (3,000 foot) flight altitude.

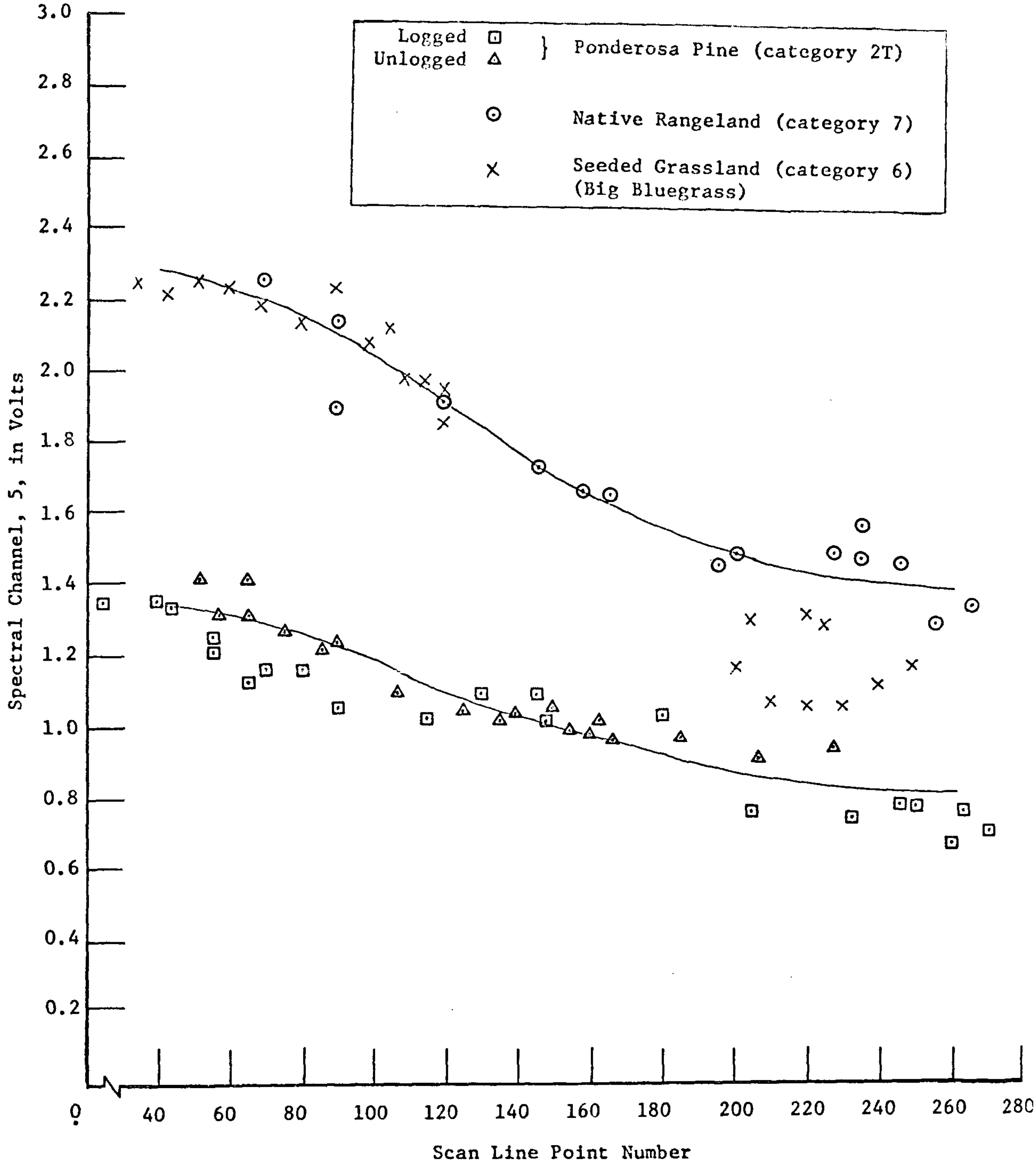



Figure 3.- The smooth curve representation of the polynomial scan angle functions for units 2T (ponderosa pine forest), and 7 (native range) from data in spectral channel 5 (0.0478 - 0.0508 μm). The points for seeded big bluegrass (unit 6) illustrate the relative radiance differences from the beginning and end of the scan line.

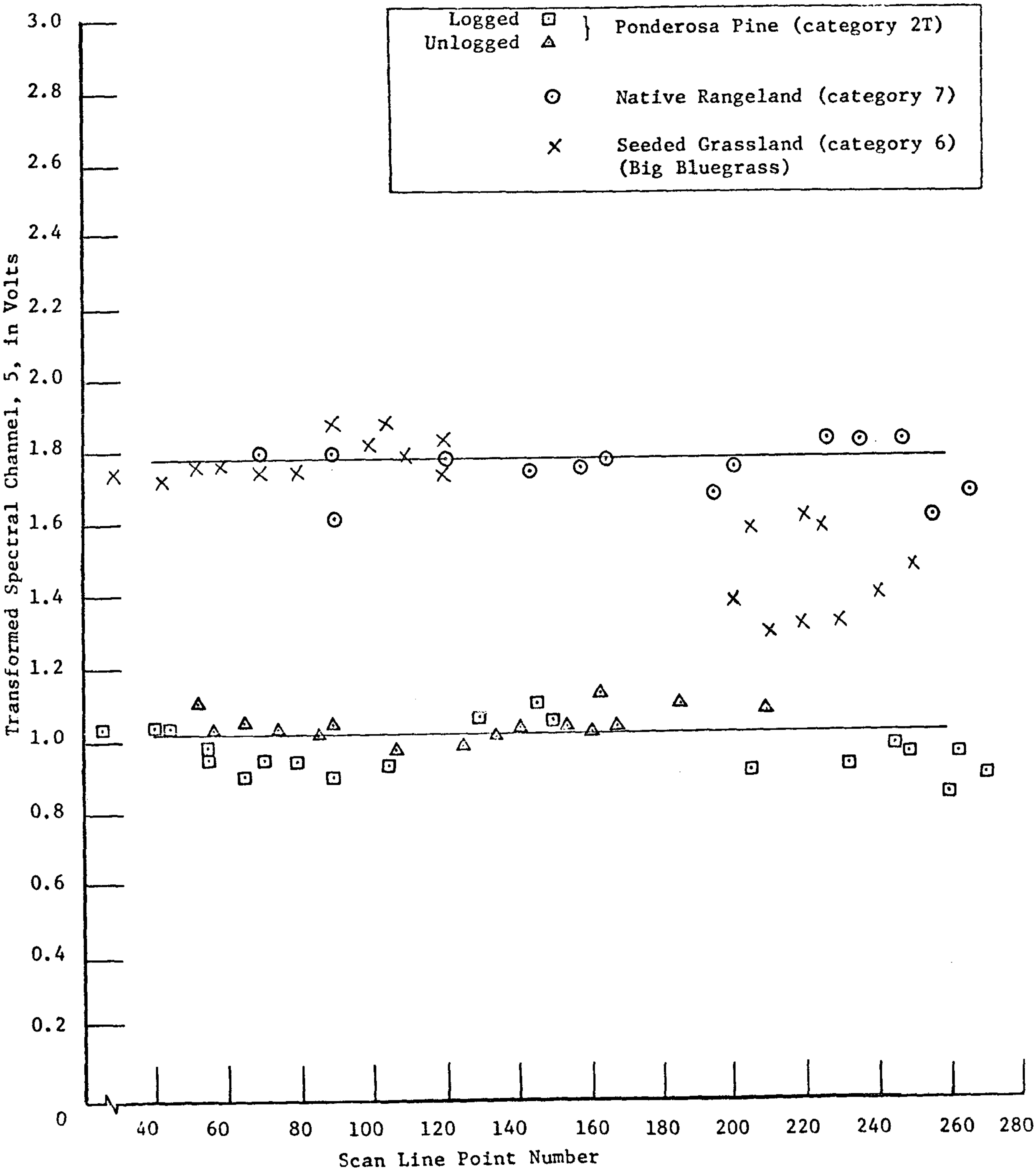
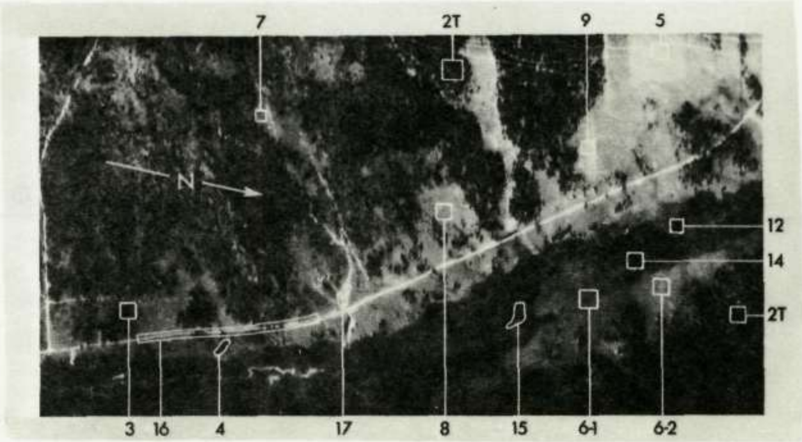



Figure 4.- Normalized data from channel 5 (0.0478 - 0.0508 μm) with the scan angle effect eliminated. The point scatter for the big bluegrass seeding at the high scan line numbers indicate a heterogeneous population based on apparent radiance signals in this data channel.

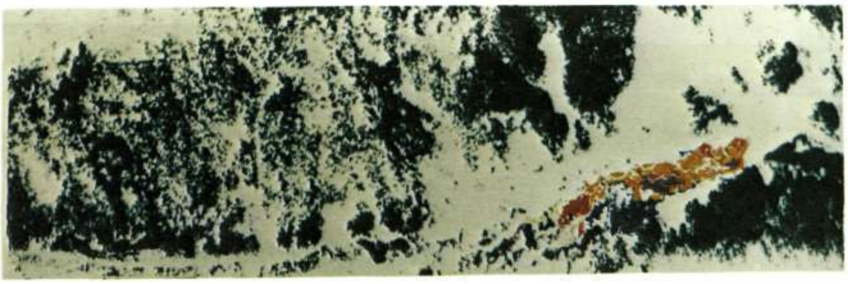



Legend

| | |
|---|---|
| 2T | Ponderosa pine forest |
| 3 | Dense natural ponderosa pine regeneration |
| 4 | Dense planted ponderosa pine regeneration |
| 5 | Seeded grassland (crested wheatgrass) |
| 6 | Seeded grassland (big bluegrass) |
| 7 | Native grasslands |
| 8 | Abandoned fields with native vegetation different from 7 |
| 9 | Other seeded rangeland |
| 12 | Willow type vegetation |
| 14 | Native bluegrass meadows |
| 15 | Sedge/rush/bulrush meadows |
| 16 | Asphalt roads |
| 17 | Bare soil (alluvial fans, unstable gullies) |

Figure 5.- Location of training area identified by category (map unit) number.

Figure 6.- Color digital recognition map of three ponderosa pine forest communities, five upland grassland communities, three hydrophyllic communities, and two nonvegetation categories. The training area map (Fig. 5), and photo map of the area (Fig. 1) will aid in interpreting this map. Most serious mixing of category recognition was between the big bluegrass seeding (category 6) in the upper right corner of the map and the two native upland grassland communities (categories 7 and 8).



(a)

(b)

Figure 7.- Color recognition maps from SPARC processing using the six normalized spectrometer channels (channels 5, 6, 7, 9, 10, 12). Refer to Table 5 for the color coding of these maps.

N72-29416



SECTION 124

# CORN BLIGHT WATCH EXPERIMENT RESULTS

ORIGINAL CONTAINS COLOR ILLUSTRATIONS

by

C.J. Johannsen, M.E. Bauer, and Staff*
Laboratory for Applications of Remote Sensing (LARS)
Purdue University
West Lafayette, Indiana

Many results were obtained from an experiment as large as the Corn Blight Watch Experiment. This discussion will concentrate on results pertaining to the detection and assessment of the severity and extent of southern corn leaf blight in the Corn Belt area by ground observations, interpretation of color infrared photography, and machine analysis of multispectral scanner data.

## GROUND OBSERVATIONS

Biweekly ground observations provided comprehensive information on the development of SCLB in 1971. The sample design enabled the ground observation data from 8-10 biweekly fields to be expanded to estimate acreages of corn in each blight severity level for each segment, flightline, and total seven-state area. These estimates are highly accurate for the entire experimental area and the intensive study area and less accurate at the flightline and segment levels.

Estimates of proportions of acres in each blight severity class for the eight biweekly observation periods are summarized in Figure 1. In June and July blight was widespread across the Corn Belt area, but Figure 1 indicates that it was restricted to a small acreage and the severity levels were quite low. By early August a significant portion of the acreage was infected at the low blight levels of 1 and 2 and about five percent of the acreage had moderate (level 3) infection. From this time on the extent and severity of infection depended on weather conditions occurring during the remainder of the season.

There was an increase in the acreage becoming infected during mid-to late-August, but only 20 percent of the acreage was infected at moderate or severe levels (levels 3 or 4) and less than five percent

---

*Work and resources to conduct the Corn Blight Watch Experiment were funded by the many participating agencies. LARS effort of the Experiment was funded in part by the National Aeronautics and Space Administration (NASA) under Grant # NGL 15-005-112.

was very severely infected (level 5) by the last week of August. By this time most of the corn was at the dent stage of maturity and further increases in infection level had little or no effects on yields. During the last two observation periods higher infection levels were reported; however, some of these estimates may have been conpounded by the effects of normal maturity and senescence, making it difficult to accurately rate blight damage alone in the field.

## INTERPRETATION OF COLOR INFRARED PHOTOGRAPHY

The photointerpretation results can best be examined by comparing the photointerpretive estimates of blight severity with those made from ground observations. The first level of comparison will be estimates of the total number of acres in each blight severity level for the entire experimental area (Figure 2). There is close agreement between the two estimates at all blight levels except 0 and 1. The higher number of acres of blight level 0 estimated by photointerpretation indicates that slightly infected corn could not be distinguished from corn with no infection using photointerpretation techniques, therefore corn with level 1 infection was probably called blight level 0 (healthy corn) in many cases. Preliminary examination of the variances of these estimates shows that variances for field and photointerpretive estimates are of similar magnitude.

Photointerpretive and field observation results can also be compared at the flightline level. At the same time the variables geography and time can be observed since we will be looking at maps showing the location of different blight infection levels at several times during the season. The average blight severity level for each flightline according to ground or photointerpretative estimates was computed from the expanded acreage of corn in each blight level in the flightline. The range of estimated blight severity levels was divided into four classes for presentation. Figures 3 to 6 make these comparisions for the periods beginning July 26, August 9, August 23 and September 6.

The estimated average blight severity for field observations during the July 26-August 8 period was less than 1.50 for every flightline. Photographic data from the 14 available flightlines showed good agreement with the ground data in that 13 of 14 flightlines had estimated blight levels less than 1.50 (Figure 3). The remaining flightlines were not flown due to aircraft mechanical problems and unfavorable weather.

During the two week periods beginning August 9 (Figure 4) and August 23 (Figure 5) the photointerpreters tended to slightly over-estimate the average blight levels relative to ground estimates. This is largely due to the difficulty of distinguishing blight effects from effects caused by other factors which appear similar to blight damage on the infrared film. Some of these factors include other diseases, drought damage, insect damage, and nutrient deficiencies. Work is continuing to further quantify and similarities and differences in appearance of these factors on color infrared film.

Unfavorable weather prevented collection of photography over the eastern half of the area during the period from September 6-19 (Figure 6). For those flightlines where comparisons can be made, there is good agreement between ground observations and photointerpretation results.

Although ratings of blight severity were made in many fields across the Corn Belt, an average of only eight fields per segment were checked on the ground. Most of these fields were used for training. To make the best tests of classification accuracies, ratings would be needed from many more fields so that field by field comparisons could be made. However, only a limited number of fields are available for this kind of test. Therefore, other kinds of statistical analysis have been used to evaluate the classification results. One of the procedures used was correlation. Correlation is a quantitative measure of the degree of agreement between the two methods, both of which are known to be subject to experimental error. Close agreement between field observations and photointerpretation (or machine analysis of multispectral scanner data) means that the two methods are estimating the same value for the parameter.

To more quantitatively illustrate the same data shown on the previous maps, plots of field observation estimates versus photointerpretive estimates are presented in Figure 7 for two periods. Segment means are shown in Figure 7 whereas flightline means were shown in Figures 3,4,5, and 6. Note that there is an increase in the correlation coefficient (r) for the later period when more levels of blight were present. The 1:1 line is shown as an aid in determining when there is good agreement between the two methods; it should not be confused with a regression line. Perfect agreement between the two methods would result in all points falling on the 1:1 line. A consistent bias (either over-or under-estimation) would still result in high correlation.

A major objective of the experiment was to determine if healthy corn could be distinguished from diseased corn by remote sensing methods. The graph of correlations for two classes of blight severity (0-1-2 and 3-4-5) indicates that the corn fields could be accurately separated into the two classes, healthy or slightly blighted and moderately to severely blighted (Figure 8). The data points in Figures 8 and 9 represent acres of each blight severity class in a segment. Correlation coefficients of .90 and .64 were obtained for the two classes, respectively. Similar results were obtained for the segments in the intensive study area (Figure 9). There was a tendency, however, for photointerpretive results to underestimate the acreages in the healthy corn class and overestimate the acreages in the moderate to severe blight class as compared to ground estimates. Attempts to differentiate the six individual blight classes which can be distinguished on the ground were unsuccessful. This is indicated by the low correlation coefficients (r = .21 to .67), the "scatter" of the data points, and the large deviation from the 1:1 line (Figure 10). This is not surprising since differences between individual classes are subtle. The early stages of infection are confined to the lower leaves which are hidden from the view of the sensor.

Classifications into three groups (blight levels 0-1, 2-3, and 4-5) gave results intermediate to those shown here. Correlations were higher than for the six classes, but somewhat lower than for two classes.

Several photographic variables may have affected the photointerpretation results and complicated the task of blight assessment by photointerpretation. Examples of these variables are shown in Figure 11 for two segments. Changes in illumination conditions, haze, terrain features, and other factors could not be controlled. For example, the film was oversaturated for the flight period July 26-August 9. The problems encountered with film emulsions and changes in film batches were discussed by Blilie and are evident in the examples in Figure 11.

During the Experiment, the photointerpreters were requested to identify all the cover types occurring within a given tract in each segment for each flight period. The results from this analysis for segments in central Iowa are shown in Figure 12. The photography of segment 116 is typical of the photography for the area and is shown for comparison purposes. Corn was usually identified with over 90 percent accuracy for all mission periods. The accuracy of identifying soybeans increased, in general with each period. Identification of oats decreased after July 26 because the crop had been harvested. Pasture and hay crops varied in identification accurracy.

## MACHINE ANALYSIS OF MULTISPECTRAL SCANNER DATA

In the intensive study area multispectral scanner data were collected along with ground observations and color infrared photography. A comparison of three methods of estimating the total acres in each blight class for the entire intensive study area is shown in Figure 13. The ground estimates and machine analysis estimates agree closely and have similar variances. Using photointerpretation techniques blight level 1 was greatly underestimated and blight level 3 overestimated compared to the other two methods.

The correlation of segment average blight levels as estimated by field observations and machine analysis of multispectral scanner data are shown in Figure 14 for four periods. During the earlier two periods fewer acres of moderate and severe blight were present and the correlation coefficients were relatively small. The variability may be due in part to the different procedures used by LARS and WRL in the analysis of this data.

There was much better agreement between the ground observations and machine analysis results for the two later missions as evidenced by the higher values (.86 and .90) and the close fit to the 1:1 line. As shown earlier for photointerpretation, the two earliest stages of blight infection are difficult to detect remotely.

The separation of fields into either healthy or blighted categories is shown in Figure 15. There is excellent agreement between the field observations and the estimates made from analysis of the multispectral scanner data. The data are the number of acres in each class for each of the 30 segments in the intensive study area. Correlation coefficients were .94 and .92 for the two classes and the points lie close to the 1:1 line. As with photointerpretive methods, attempts to classify the number of acres in each individual blight level were less accurate than for either two (Figure 16) or three classes.

There are many analyses which can be performed on data collected for the Corn Blight Watch Experiment. These analyses will be continued and results reported at future dates. There are many variables which can be evaluated for their effect on the results. Variables such as planting date, plant population, cytoplasm type and other stresses were not covered in this paper.

## SUMMARY AND CONCLUSIONS

During the critical ear-filling period in August, ground observations showed there was little blight present in Nebraska, Minnesota, western and central Iowa, and the northern portions of Illinois, Indiana, and Ohio. The expansion of ground observations to total area, flightline, and segment estimates provided a basis for evaluating results from analysis of color infrared film and multispectral scanner measurements.

Healthy or slightly infected corn was accurately differentiated from moderately or severely blighted corn using photointerpretive techniques. Slight and mild levels of blight infection were not detected using the color infrared film. Variables such as soil differences, varietal differences and the presence of other stresses complicated the task of differentiating blight levels.

Accurate estimates of the acreages of healthy and blighted corn in the intensive study area were obtained from the machine analysis of the multispectral scanner data. There was high correlation and agreement between ground estimates and machine analysis estimates. Analysis of multispectral scanner data gave a more accurate assessment of the blight situation than that provided by photointerpretation methods when compared with expanded ground observations. Corn was identified with a high degree of accuracy by both photointerpretive and machine analysis methods throughout the season.

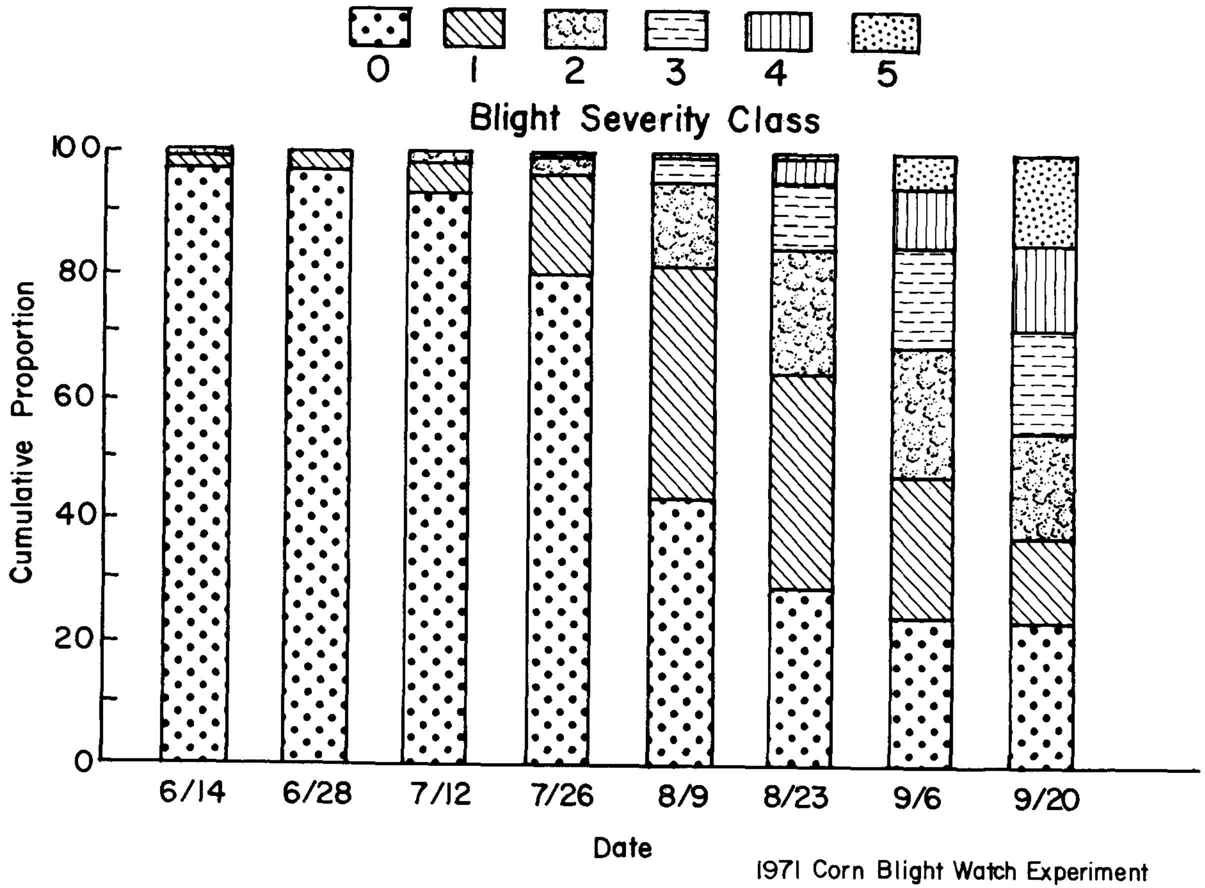



Figure 1. Proportion of acres in each blight severity class as estimated by ground observations for eight observation periods.

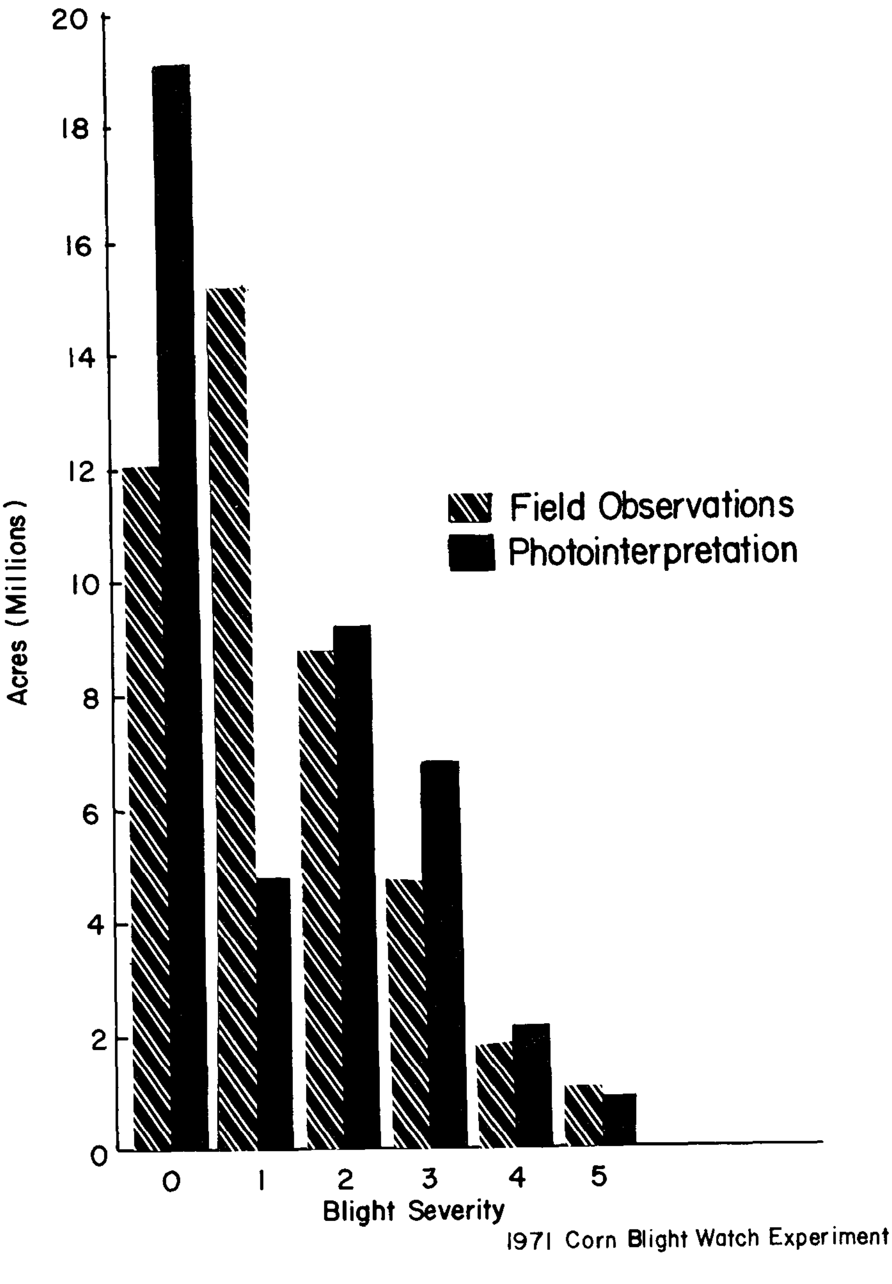



Figure 2. Comparison of field observation and photointerpretation estimates of corn acreage in individual blight classes for August 23 to September 5.

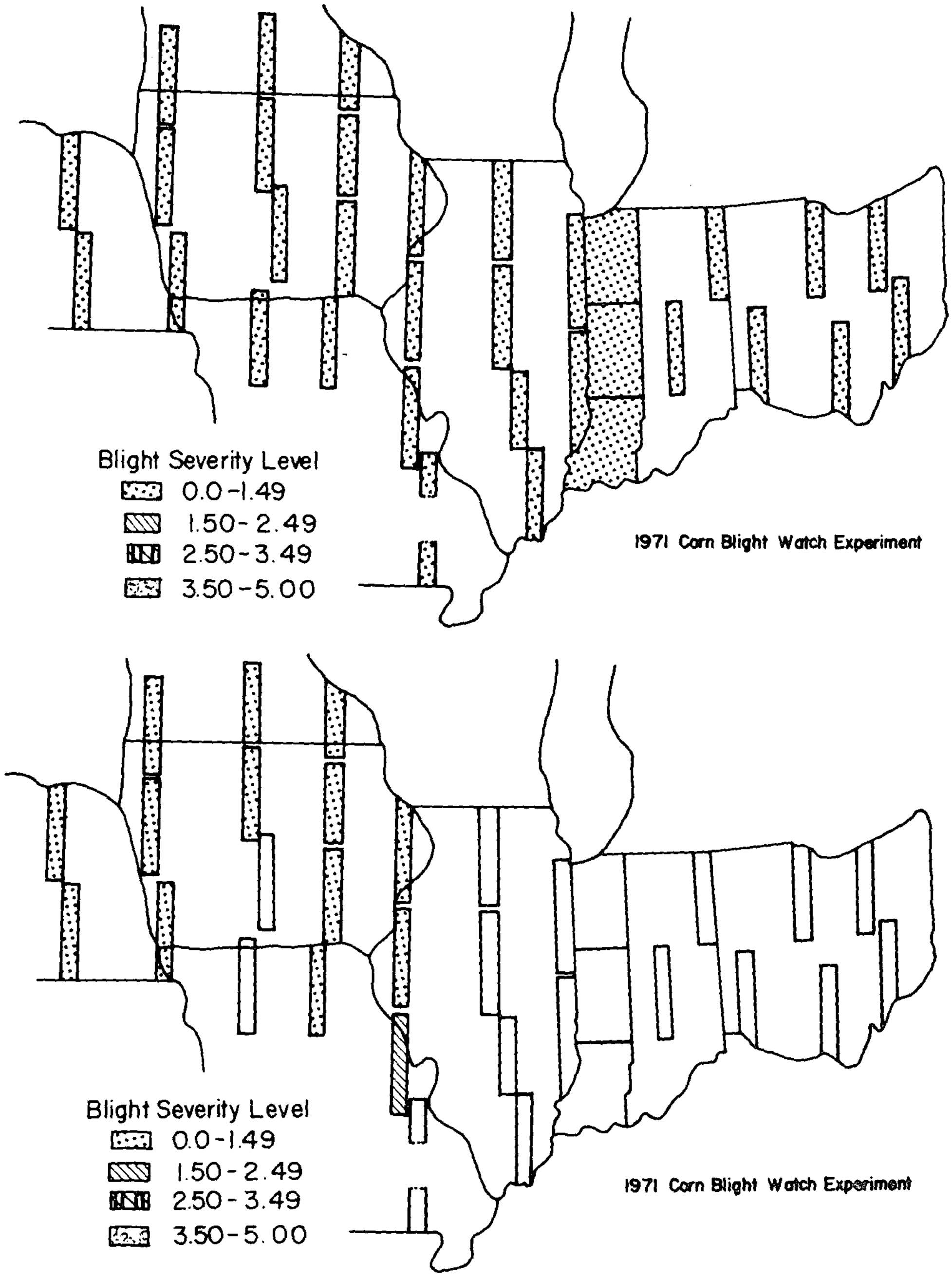



Figure 3. Average blight severity levels by flightline for field observations (top) and photointerpretation (bottom) for the period beginning July 26, 1971.

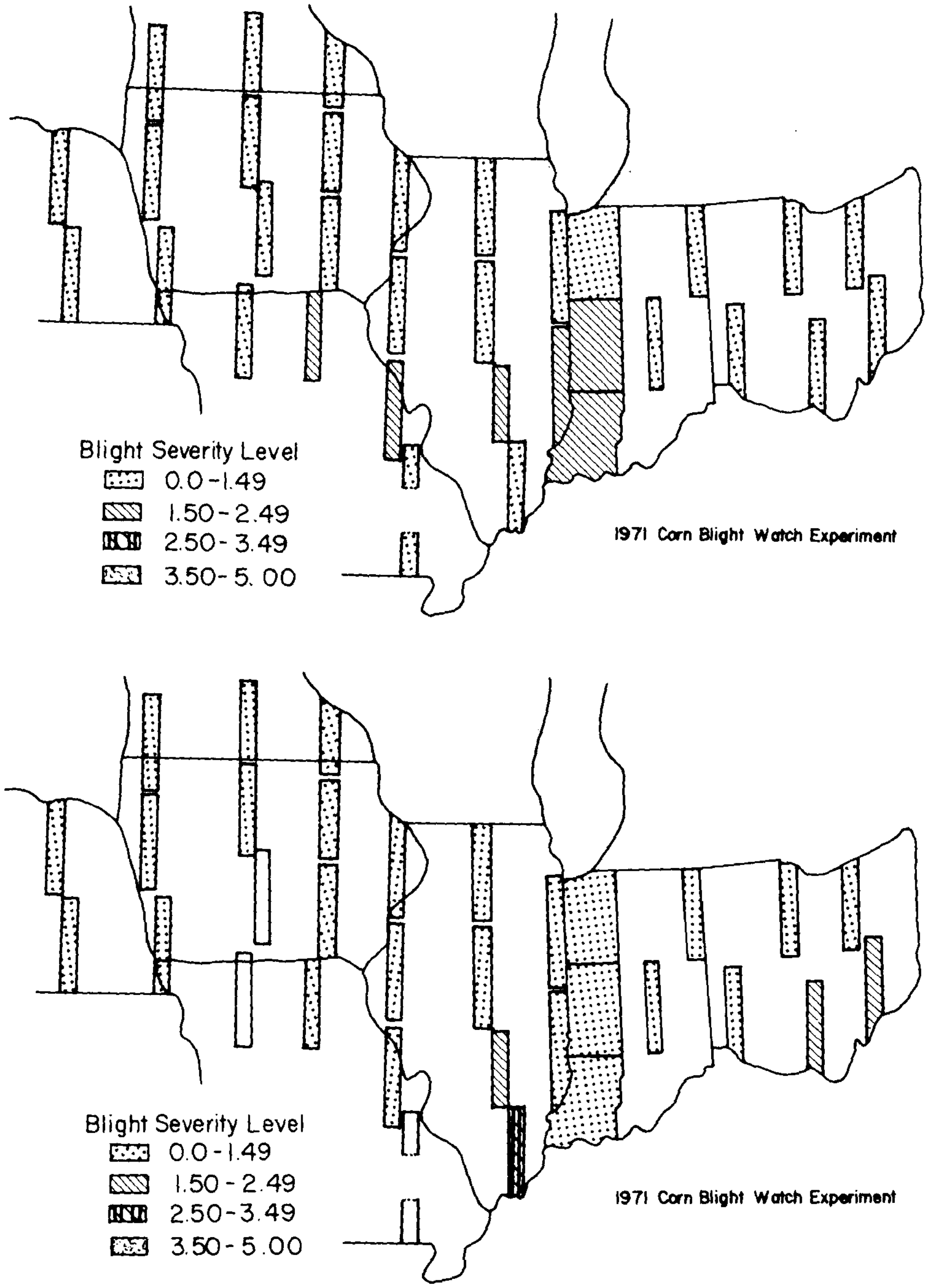



Figure 4. Average blight severity levels by flightline for field observations (top) and photointerpretation (bottom) for the period beginning August 9, 1971.

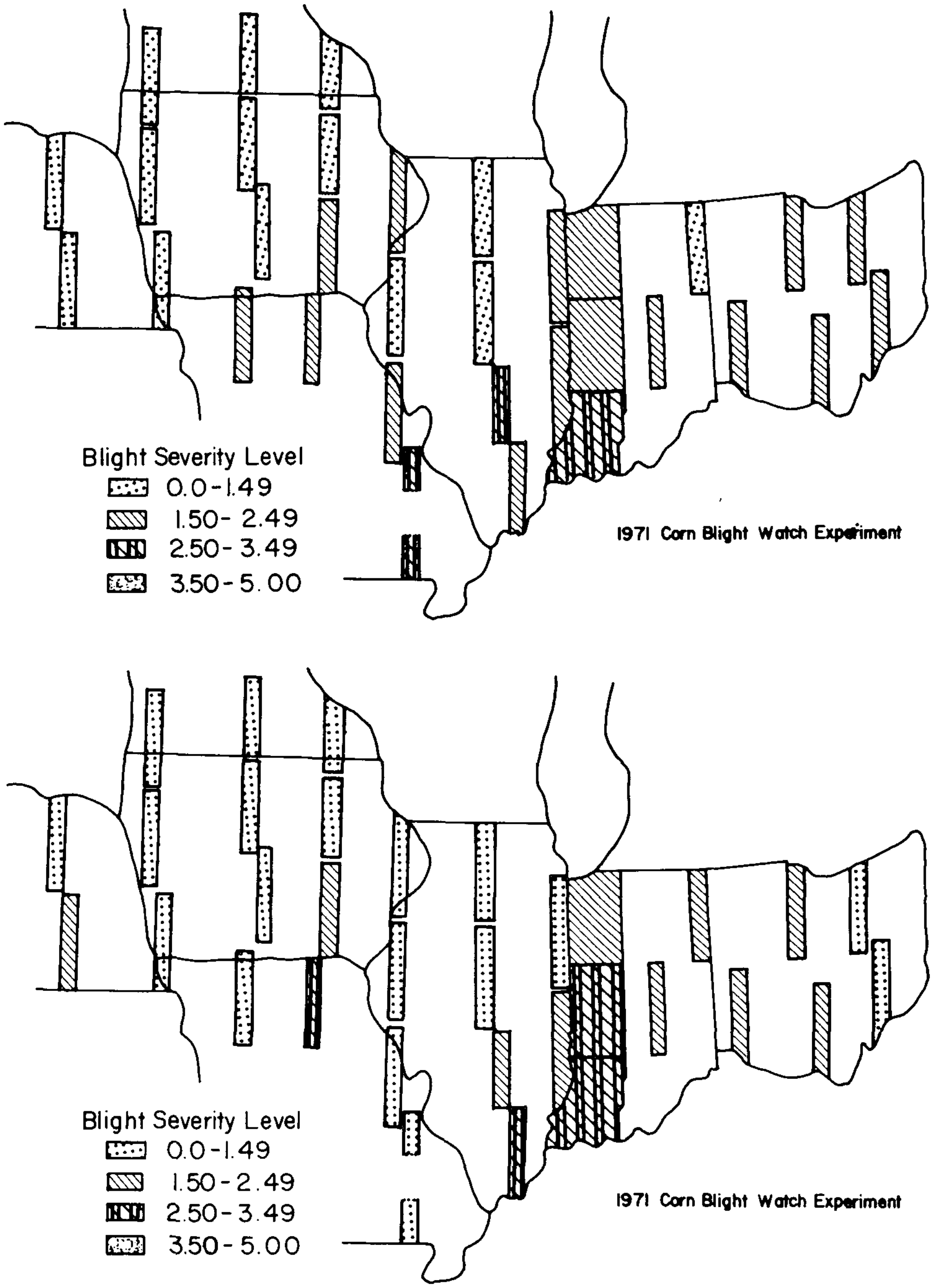



Figure 5. Average blight severity levels by flightline for field observations (top) and photointerpretation (bottom) for the period beginning August 23, 1971.

RF

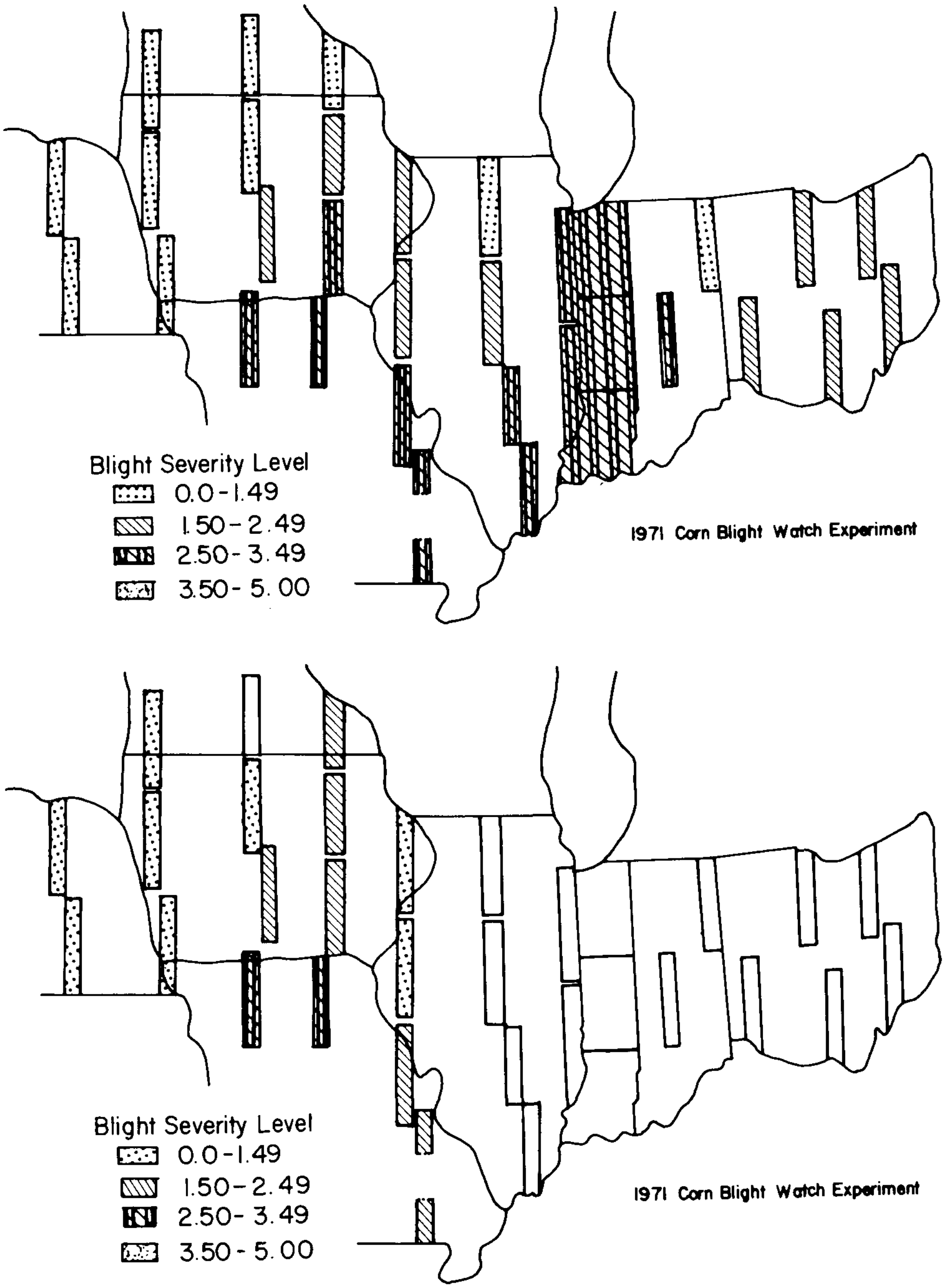



Figure 6. Average blight severity levels by flightline for field observations (top) and photointerpretation (bottom) for the period beginning September 6, 1971.

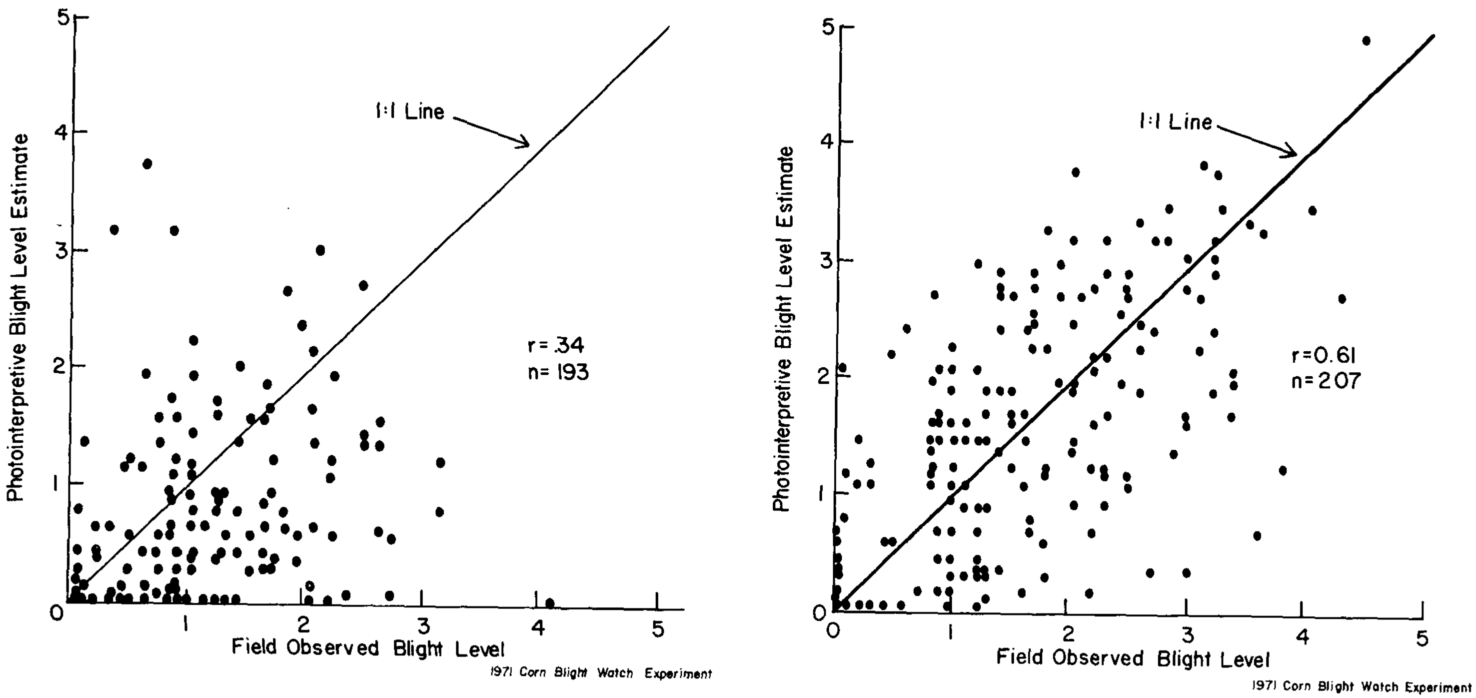



Figure 7. Correlation of field observation estimates and photointerpretation of segment averages of blight severity for the periods beginning August 9 (left) and August 23 (right), 1971.

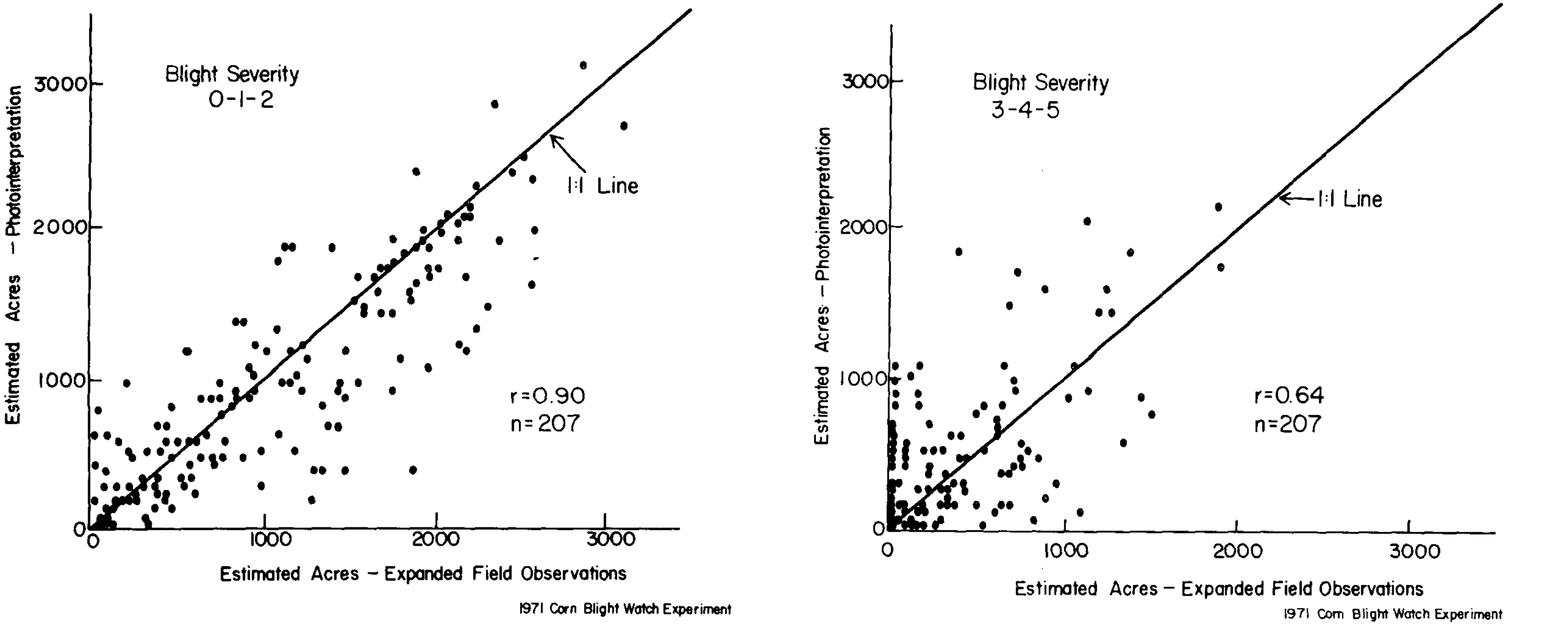



Figure 8. Correlation of field observation and photointerpretation estimates of acreages of healthy (blight levels 0-1-2) and blighted (3-4-5) corn in the Corn Belt area, August 9-22, 1971.

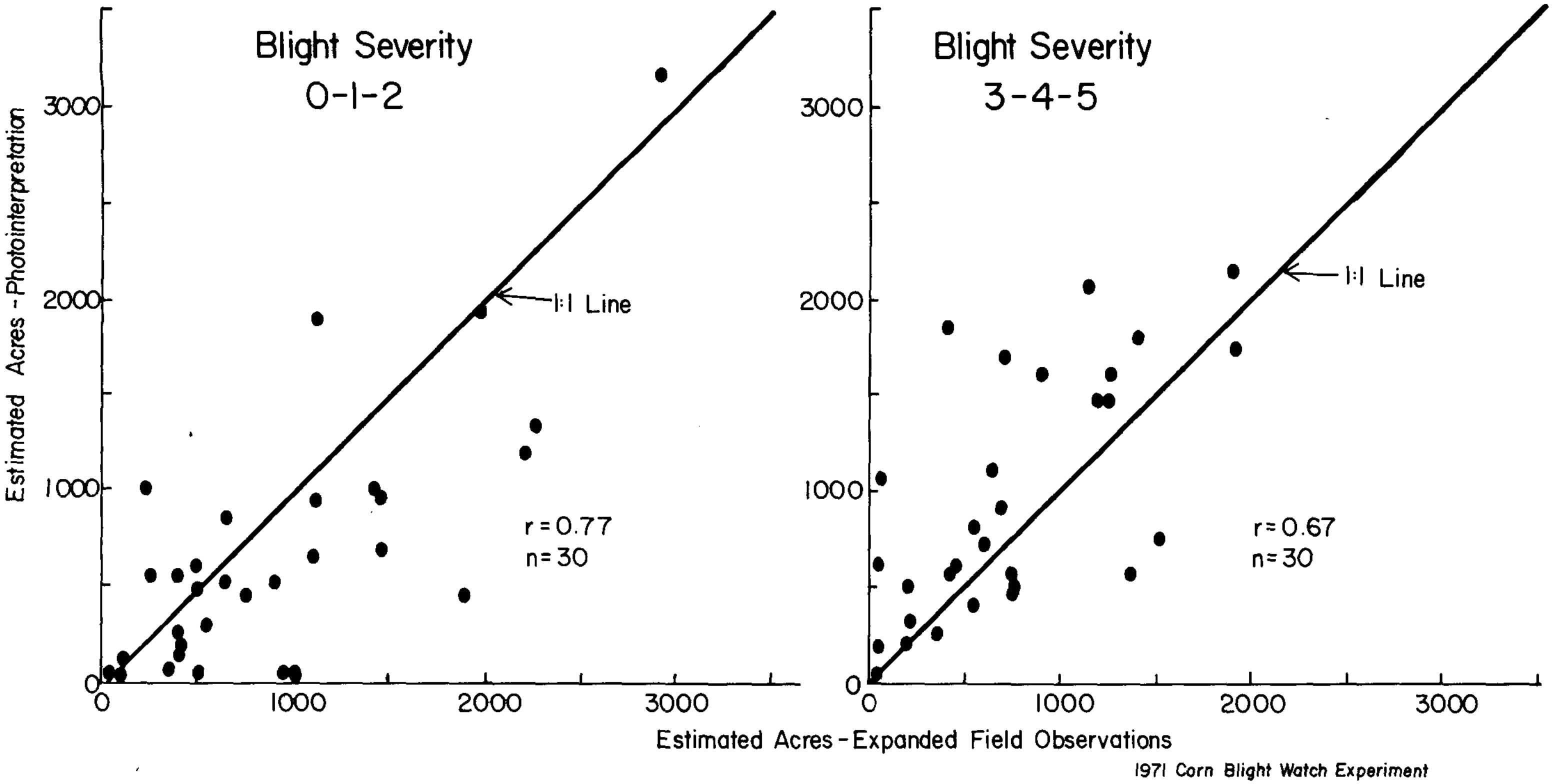



Figure 9. Correlation of field observation and photointerpretation estimates of acreages of healthy (blight levels 0-1-2) and blighted (3-4-5) corn in the intensive study area for the period beginning August 9, 1971.

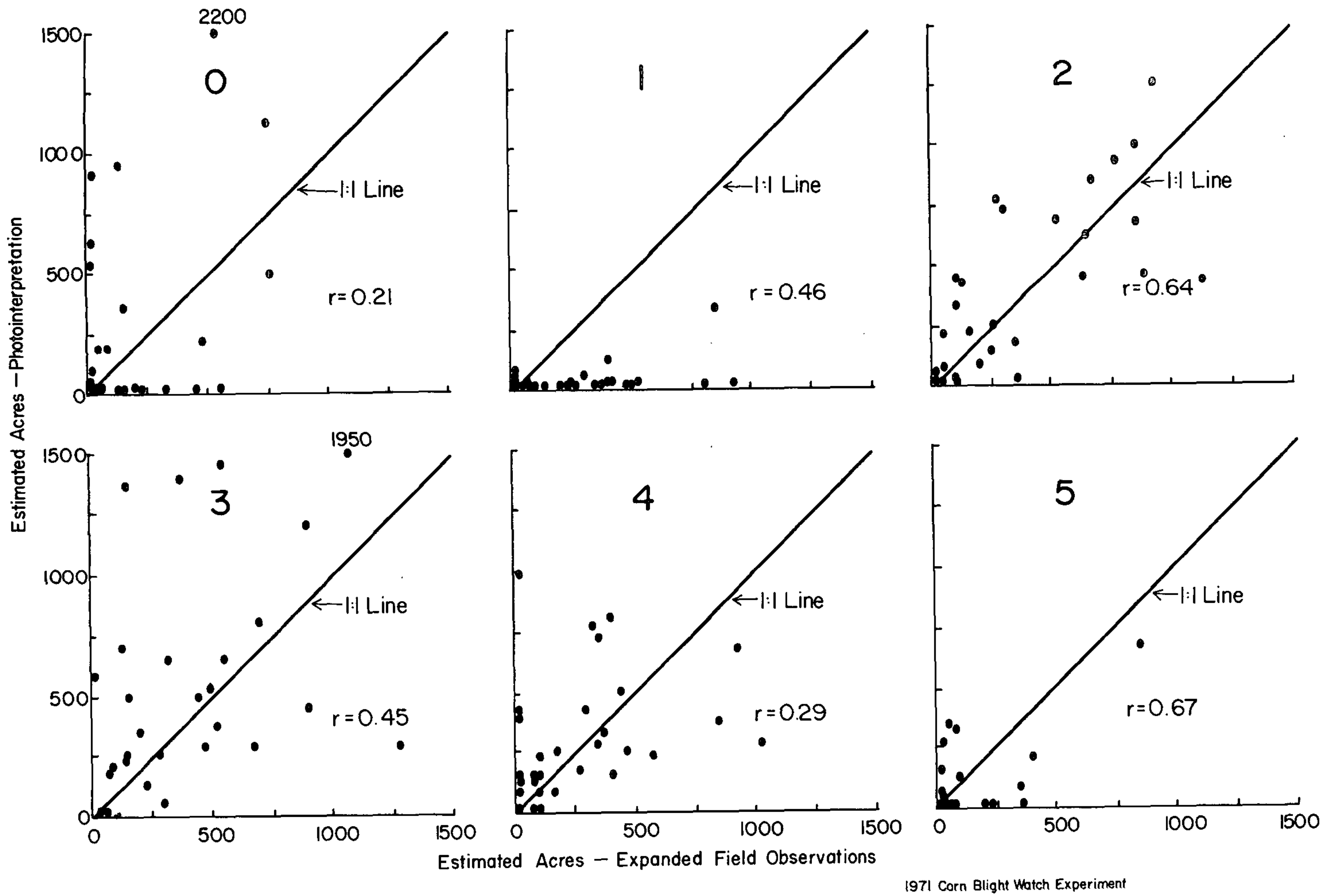



Figure 10. Correlation of field observation and photointerpretation estimates of acreages of individual blight classes in the intensive study area for the period beginning August 9, 1971.

# Color Infrared Photographs of Two Segments Through the 1971 Growing Season

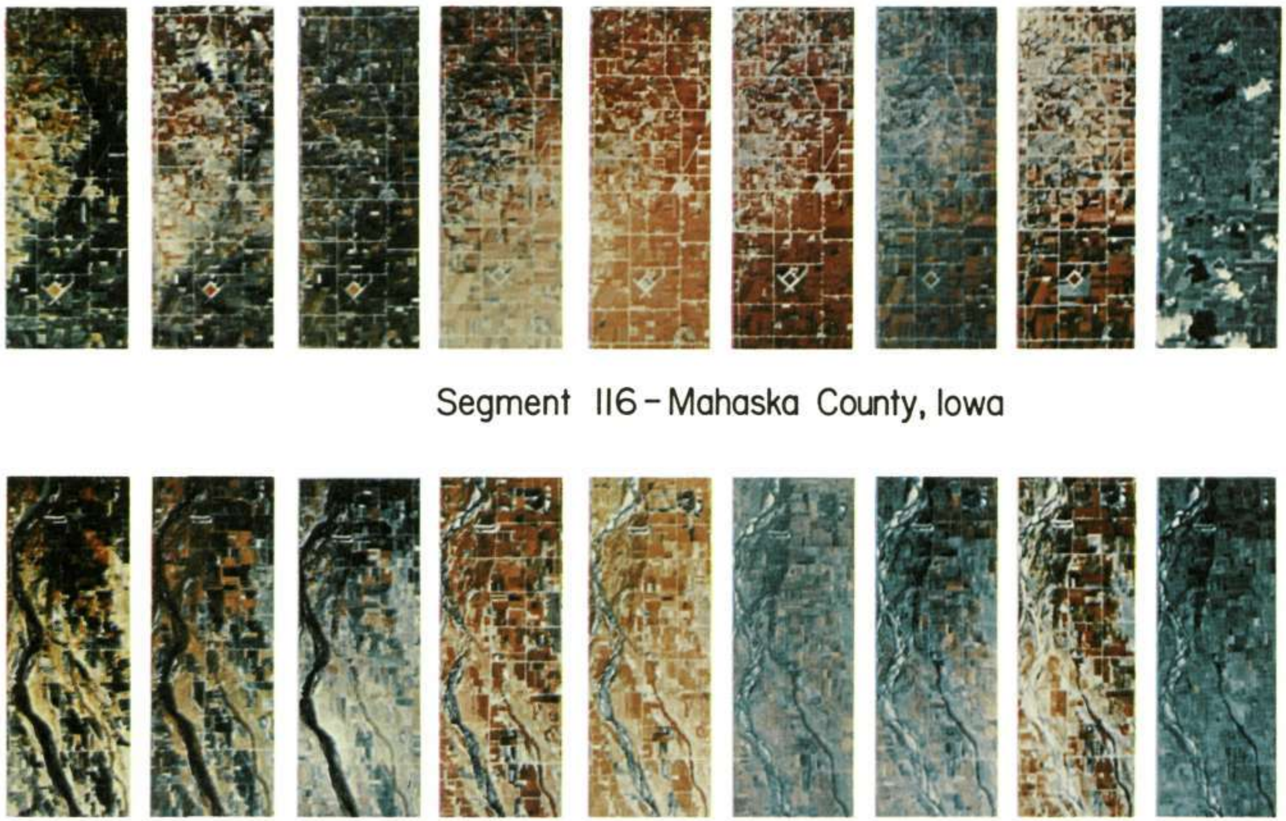



Figure 11. Color infrared photographs of segment 116 and 175 through the 1971 growing season.

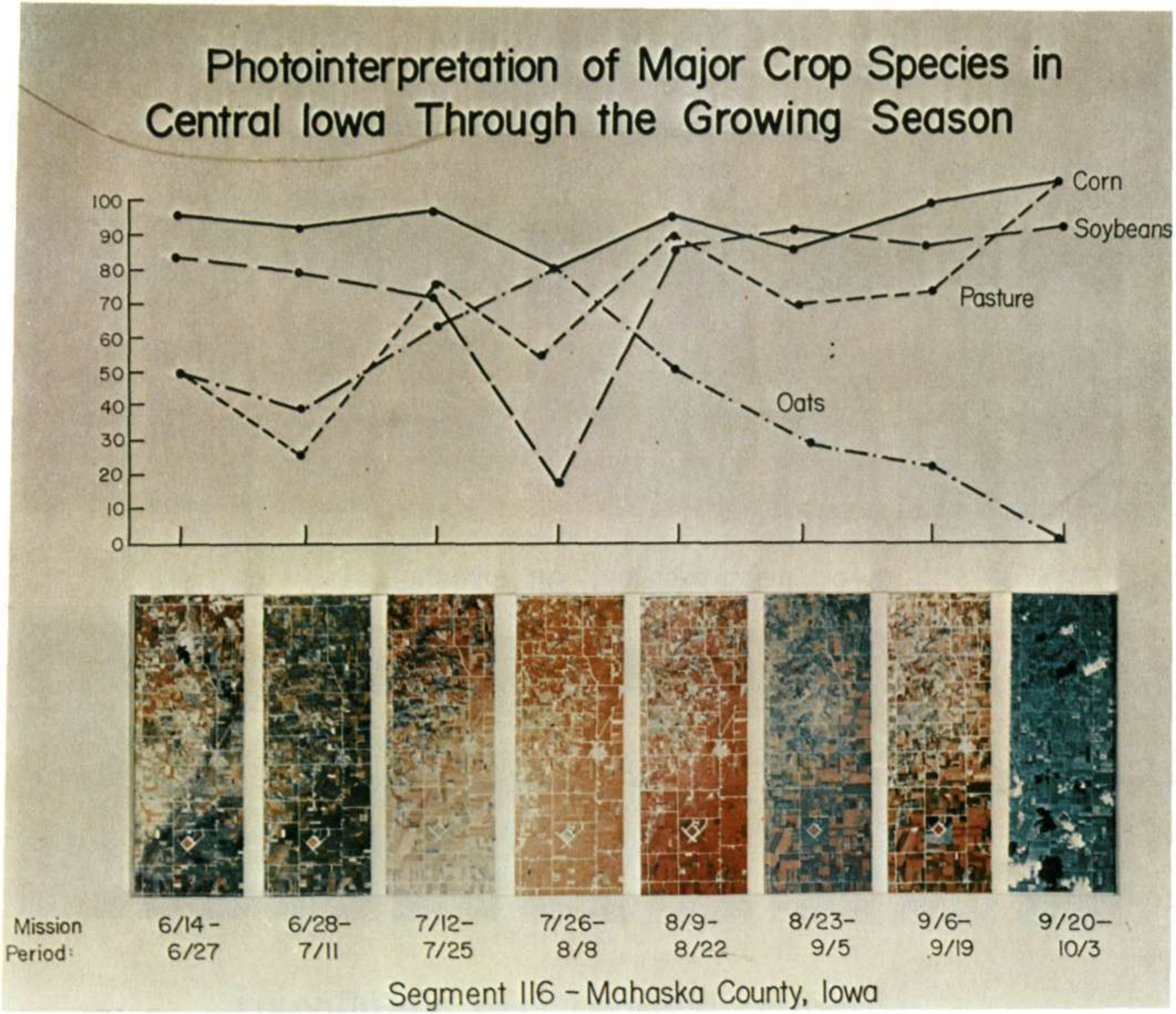



Figure 12. Identification by photointerpretation of major crop covers in Central Iowa through the 1971 growing season.

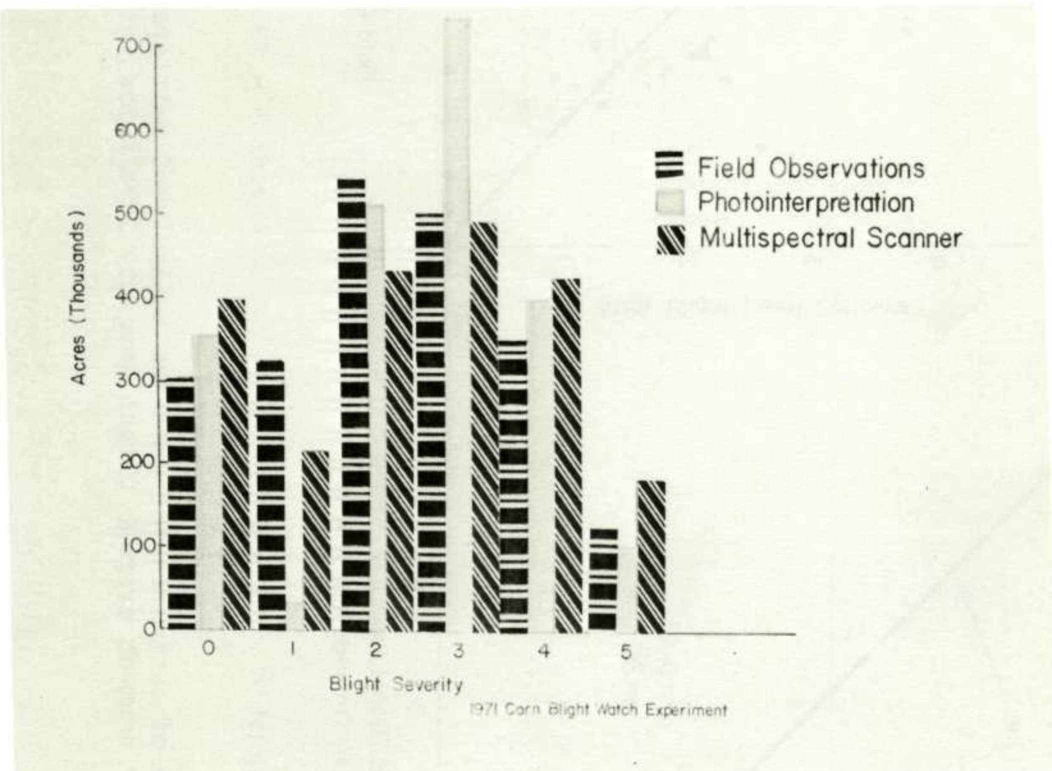
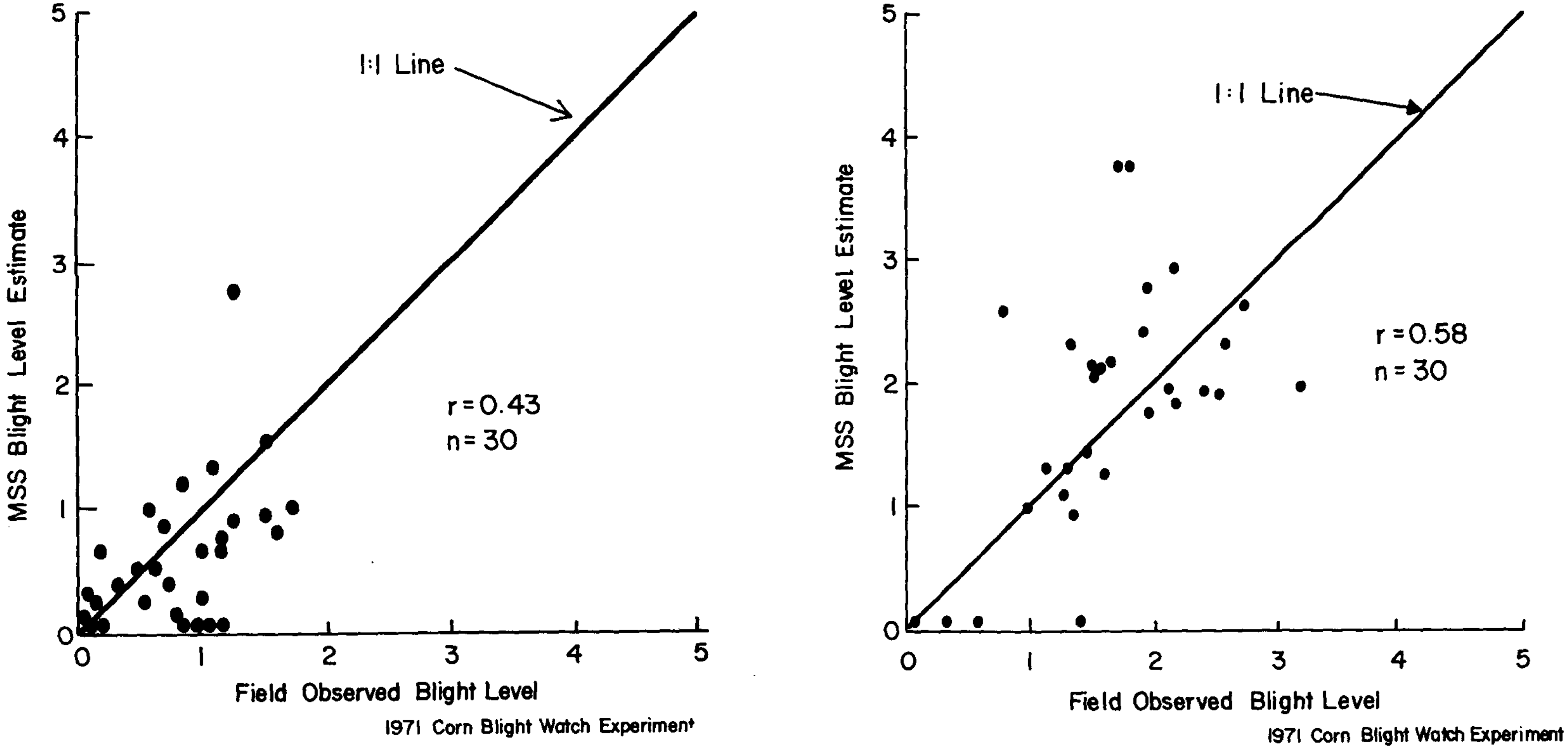


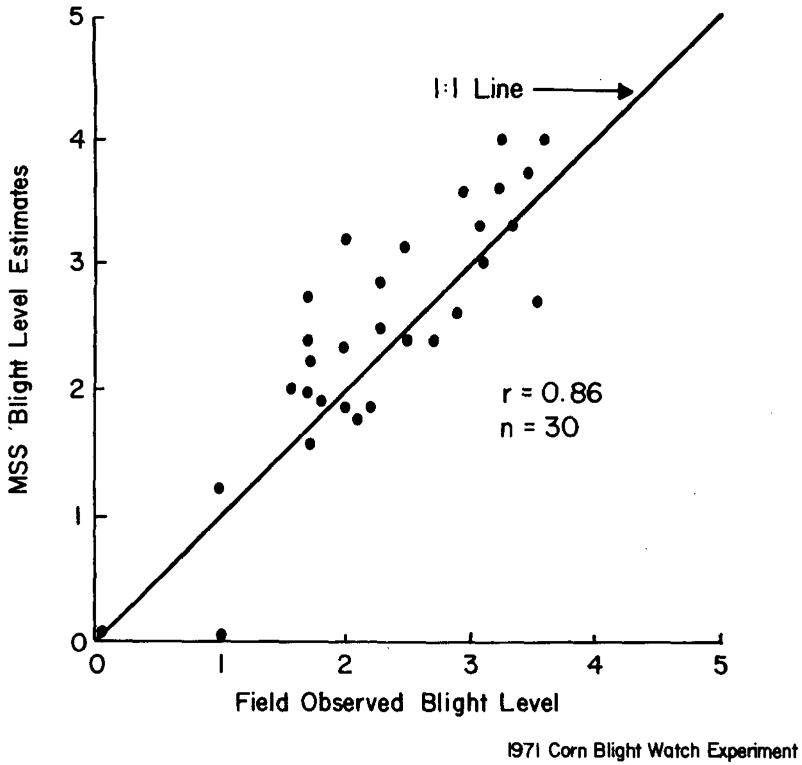

Figure 13. Comparison of field observation, photointerpretation and machine analysis estimates of corn acreage in individual blight classes for the mission period beginning August 23, 1971.



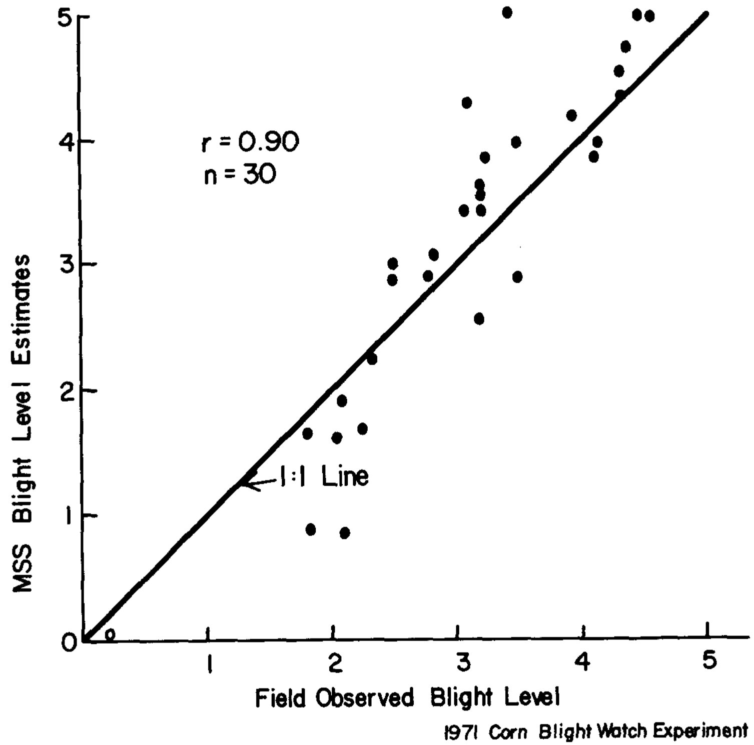

a. July 26 - August 8

b. August 9 - 22

Figure 14. Correlation of estimates from machine analysis of multispectral scanner data and field observations of segment average blight severity levels for four successive mission periods.




c. August 23 - September 5




d. September 6 - 19

Figure 14. Concluded.

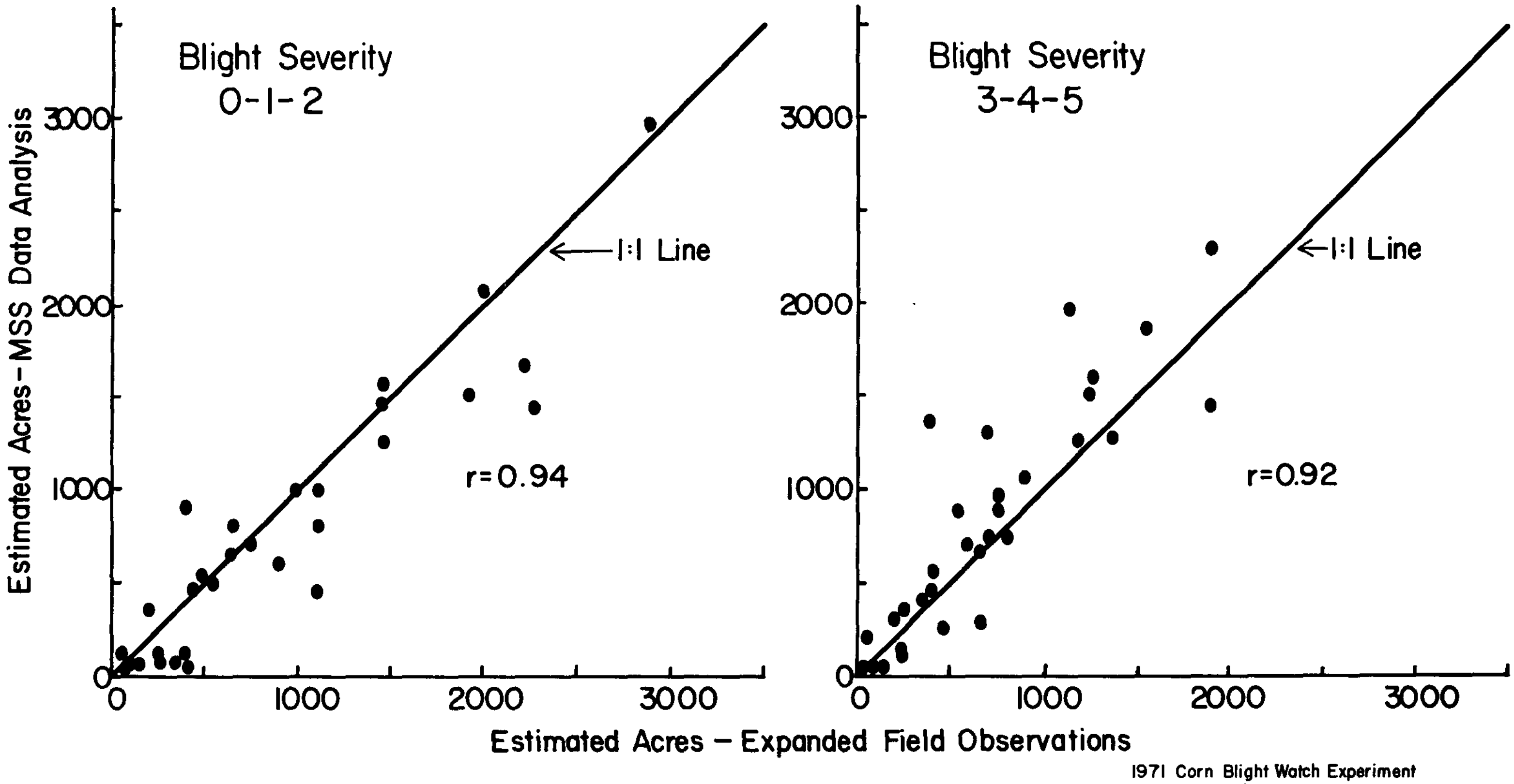



Figure 15. Correlation of estimates from multispectral scanner data and field observations of acreages of healthy (blight levels 0-1-2) and blighted (3-4-5) corn in the intensive study area for the period beginning August 9, 1971.

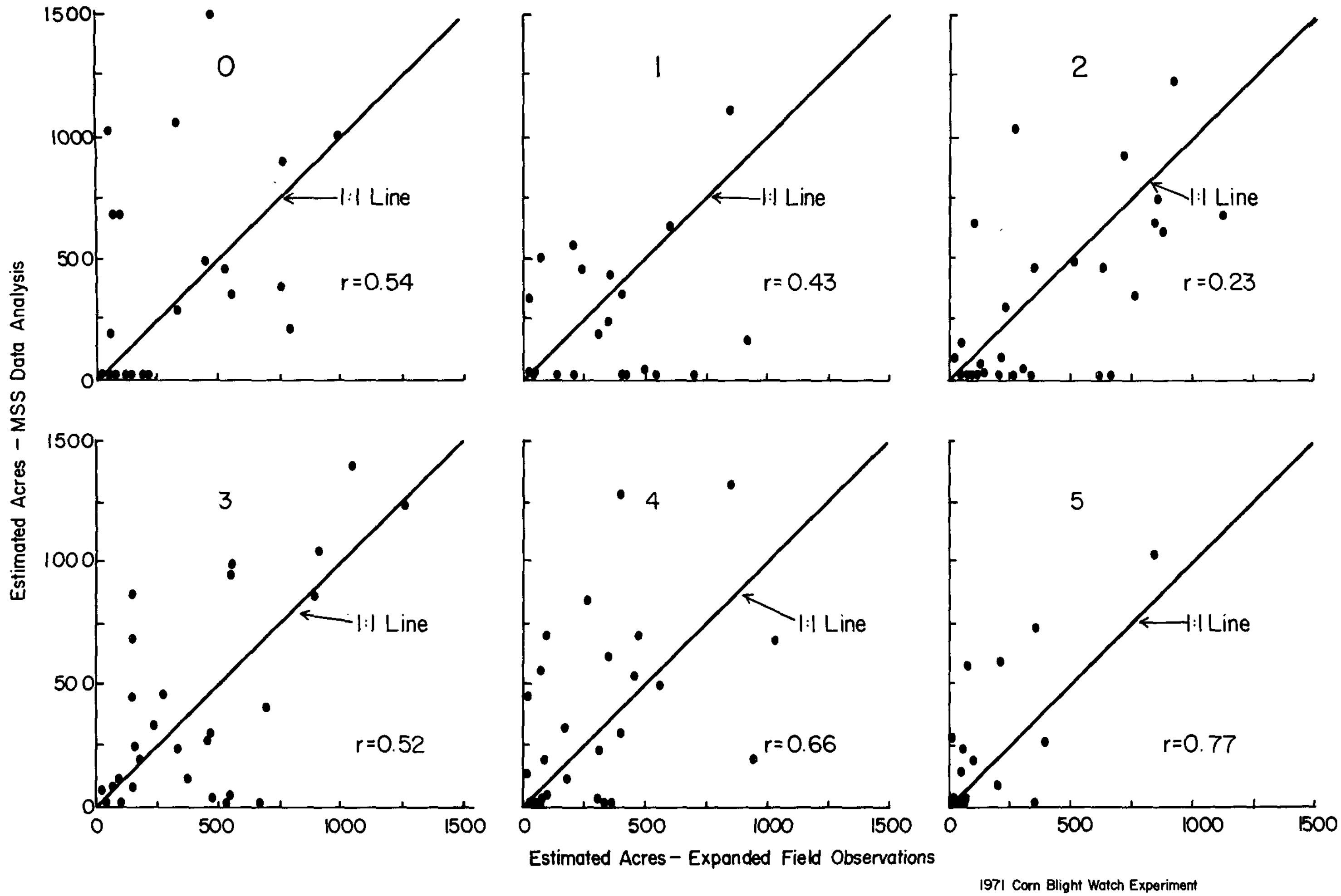



Figure 16. Correlation of estimates from multispectral scanner data and field observations of acreages in individual blight classes in the intensive study area for the period beginning August 9, 1971.

C4

N72-29417



SECTION 125

# THE CORN BLIGHT PROBLEM -- 1970 and 1971

by

Marvin E. Bauer
Laboratory for Applications of Remote Sensing (LARS)
Purdue University
West Lafayette, Indiana

## INTRODUCTION

Southern corn leaf blight is caused by the fungus *Helminthosporium maydis*. The disease has been known for many years and is widespread in tropical areas of the world wherever corn is grown. Until 1969, southern corn leaf blight (SCLB) was considered a minor disease in the United States, since it seldom caused severe leaf damage or loss in yield. At about this time, a new race of *H. maydis* (race T) adapted itself to Texas male-sterile (TMS) cytoplasm corn. The origin of the new Race T is not known. The unusual susceptibility of TMS cytoplasm corn was first recognized in scattered fields in Illinois, Indiana, and Iowa in 1969.

Since the early 1960's, male-sterile cytoplasm has been widely used by seed corn companies to lower the cost of producing seed by the elimination of hand-detasseling. An estimated 85 to 90 percent of the corn grown in 1970 contained Texas male-sterile cytoplasm. When Texas male-sterile cytoplasm was incorporated into hybrids it was not known that susceptibility to southern corn leaf blight was bared in this type of cytoplasm.

## THE 1970 CORN BLIGHT EPIPHYTOTIC

Three very important factors were responsible for the onset and development of the corn blight epiphytotic in 1970. These three factors, necessary for the development of any plant disease, are: (1) a susceptible host (in this case Texas male-sterile cytoplasm corn), (2) a virulent pathogen (in this case a new pathogenic race of the fungus *Helminthosporium maydis*), and (3) a favorable environment for the pathogen (in many diseases caused by fungi, of which SCLB is one, warm, damp weather is ideal). The absence of any one of these three factors would have prevented the widespread development of SCLB in 1970.

Race T of *H. maydis* unexpectedly spread very rapidly during 1970, from late February to June, in Florida, Georgia, Alabama, Mississippi, and other southeastern states. Tremendous numbers of spores, carried by moisture-laden northerly winds, infected corn in Kentucky, Tennessee, and eastern Missouri; later, Illinois, eastern Iowa, Indiana, Ohio, and other parts of the Corn Belt were infected. By late August, the disease was found as far north as Minnesota, Michigan, and Ontario, Canada. The rapid and widespread development of SCLB in 1970 is shown in Figure 1. Widespread drought in the western Corn Belt restricted blight development there.

Reduction in 1970 corn yields nationally from SCLB is difficult to estimate. However, corn leaf blight, combined with severe drought conditions in some areas, is estimated to have reduced 1970 corn production about 700 million bushels from the original forecast total of 4.8 billion bushels. The forecast average yield per acre on July 1, 1970 was 83.1 bushels; in December it was estimated the harvested yield was only 71.7 bushels per acre -- a reduction of 15 percent (Figure 2). In some states the average yield loss was greater and in many individual farm fields the crop was nearly a total loss.

## SYMPTOMS OF SOUTHERN CORN LEAF BLIGHT

Symptoms of SCLB are characterized by tan or light-brown spots or lesions that usually appear first on the lower leaves. Under suitable conditions wind or splashing rain carries spores to upper leaves producing secondary infections. Lesions are oblong to spindle-shaped, ranging up to about 1/2 to 1 inch in length and 1/4 to 1/2 inch in width. On very susceptible plants the lesions increase rapidly in number. The lesions may merge, severely blighting and killing the leaves. A scale showing the six stages of blight severity which can be identified on the ground is shown in Figure 3.

The lesions on the stalk, leaf sheath, and ear husks may enlarge rapidly, to as much as 6 inches in length. The penetration of the silk end of the ear or the shucks takes 7 to 14 days in damp weather, and may lead to a moldy or charcoal-like rot of the kernels and cob. The grain is destroyed. With severe leaf-killing, stalk rot by *H. maydis* and other fungi is increased. As a result there is much lodging where blight is severe.

## DEVELOPMENT OF BLIGHT IN 1971

The pattern of blight development in the Corn Belt test area during 1971 is shown in Figures 4 to 9. The maps are based on biweekly field observations made in Corn Blight Watch Experiment segments and flight lines. These observations were the most comprehensive and quantitative of any of the several operational efforts carried out to follow blight development. The data shown are average blight severity levels with appropriate weighting for the number of acres of each blight class present in each flight line.

Considering all cytoplasm types the average blight severity was less than 1.5 through July 30 (Figure 4). Although prior to this, blight had been reported present in several hundred counties in the Corn Belt. In T-cytoplasm fields mild levels of infection were developing in Missouri, southern Illinois, and southern and west-central Indiana (Figure 5).

Two weeks later there had been a further increase in the prevalence and severity of blight infection with some areas of severe infection present in Illinois and Indiana (Figures 6 and 7). By the last week of August blight infection had become more widespread with at least mild levels present in much of the eastern Corn Belt area (Figure 8). Figure 9 shows the areas in Illinois and Indiana where blight was most severe in T-cytoplasm fields. Although there was some increase in the severity of leaf infection in September, most of the crop was nearly mature and further infection would have little or no effect on yields.

## DISCUSSION

The prevalence and severity of only a few crop diseases can be accurately forecast months in advance of their onset. At the present time, SCLB is not one of these. No one could predict with certainty what the extent and severity of SCLB would be in 1971. The 1971 season with its threat of serious damage from SCLB is past and the factors which accounted for blight development can be examined.

First, except in the deep South, growers planted 5 to 20 percent more resistant, normal cytoplasm seed than had originally been expected (Figure 10).

The distribution of the resistant seed played a significant part in the pattern of blight development in 1971. A relatively larger portion of the resistant seed was planted in areas hard hit by blight in 1970, i.e. Illinois, Indiana, eastern Iowa, and Missouri. Those areas which escaped serious blight damage in 1970 planted a larger portion of susceptible, Texas male-sterile cytoplasm seed (Figure 11). As shown in Figures 4 to 9 the most severely-infected areas of the Corn Belt in 1971 were those where there was very little T-cytoplasm seed planted. In addition, the greatest acreages of corn occurred in those areas which had relatively little blight (Figure 12).

Weather, however, was the single most important factor in determining the severity of SCLB in 1971. A warm, dry spring enabled farmers to plant early (Figure 13). This, combined with favorable growing conditions in May and June, got the crop off to a fast start. In many areas the crop was nearly mature before blight infection reached significant levels.

Cool, dry weather from mid-July to mid-August significantly reduced the build-up of blight which might have otherwise been expected (Figure 14). In many areas across a large portion of the Corn Belt region, blight lesions were present on the lower leaves throughout July and August, but the cool temperatures held development of the disease in check. Below normal temperatures during this period were at the same time very favorable for ear development and high yields.

The number of acres in each blight severity class in the Corn Belt test area from August 23-27 is shown in Figure 15. Less than 20 percent of the acreage had moderate or severe infection levels and only about 5 percent of the acreage was severely infected.

Although the 1971 growing season produced the highest yields on record (Figure 16), it should be noted that about 55 percent of the acreage in the Corn Belt had slight or mild levels of infection. Had the season's weather been warmer and more humid, blight development would have been greater.

## CONCLUDING REMARKS

In 1970 an epiphytotic of Southern Corn Leaf Blight caused an approximate 15 percent loss to the nation's corn crop. The disease is characterized by small brown lesions appearing on the leaves of corn plants. With favorable weather conditions the lesions increase in size and number and may completely kill susceptible plants in 10 to 14 days. Plants with Texas male-sterile cytoplasm are most susceptible to the new race of SCLB which was present in 1970 and again in 1971.

The extent and severity of infection of SCLB in 1971 was determined by three factors. First, susceptibility of the crop -- a slightly-larger portion of the crop was planted to resistant hybrids than had originally been expected. Second, the presence of the pathogen -- the disease fungus overwintered in the Corn Belt and was present earlier than in 1970. Third, the favorability of the environment for the growth and reproduction of spores -- the cooler and less humid than normal weather in the Corn Belt was relatively unfavorable for blight development. This last factor is the major reason that the disease, although widespread, was not nearly as severe as in 1970.

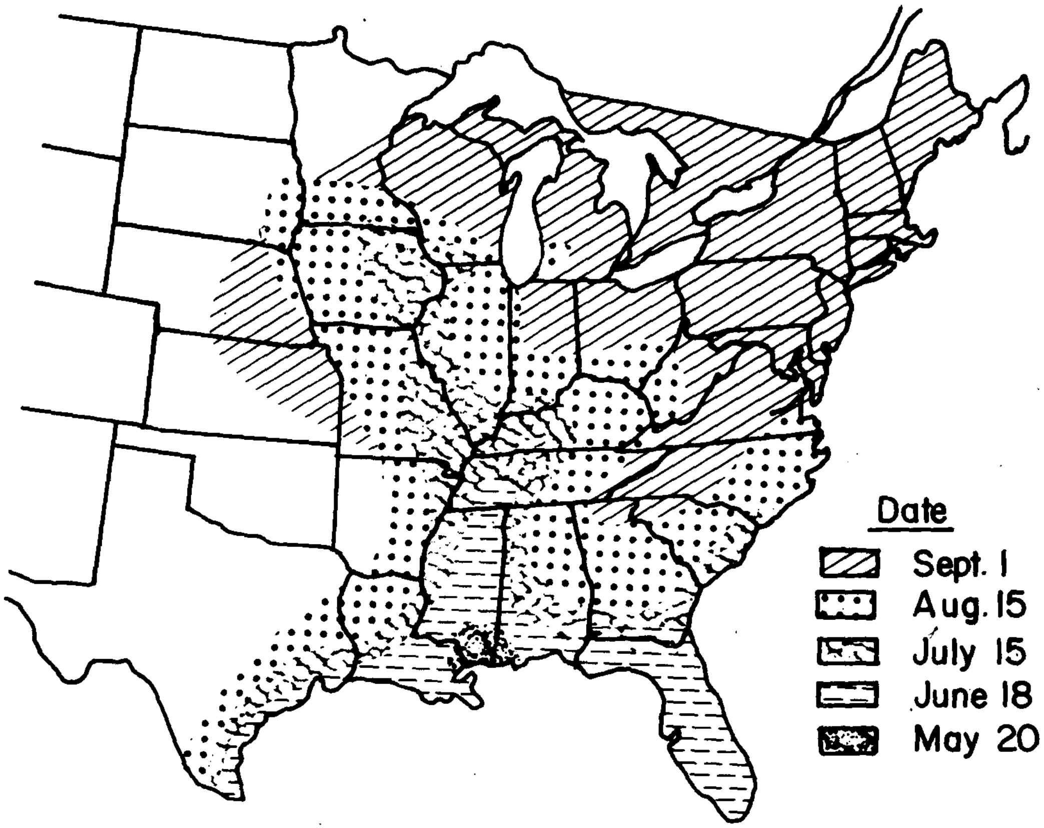



Figure 1. In 1970 southern corn leaf blight rapidly spread from the southern states to the Corn Belt.

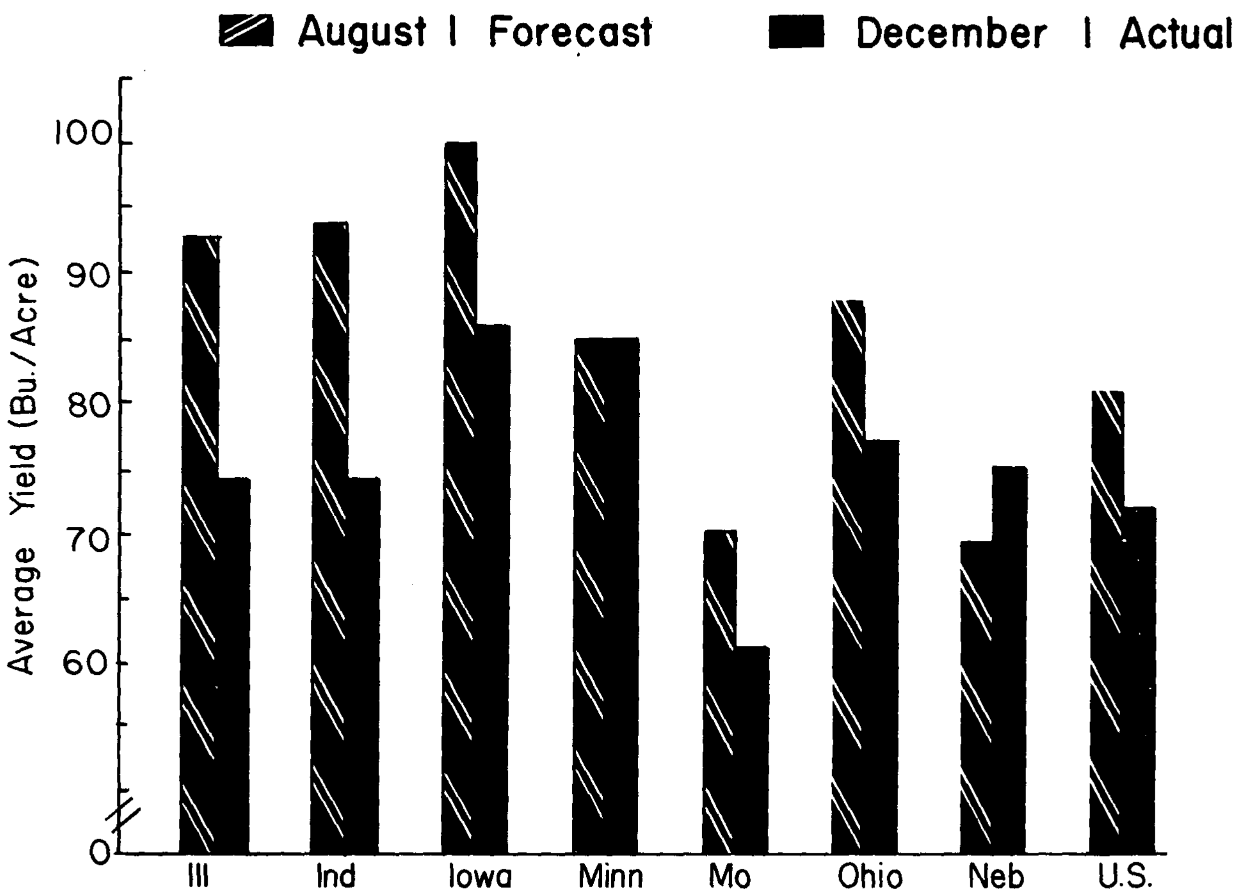



Figure 2. Yields were reduced an average of 15 percent by southern corn leaf blight in 1970. Total losses from blight were estimated to be one billion dollars.

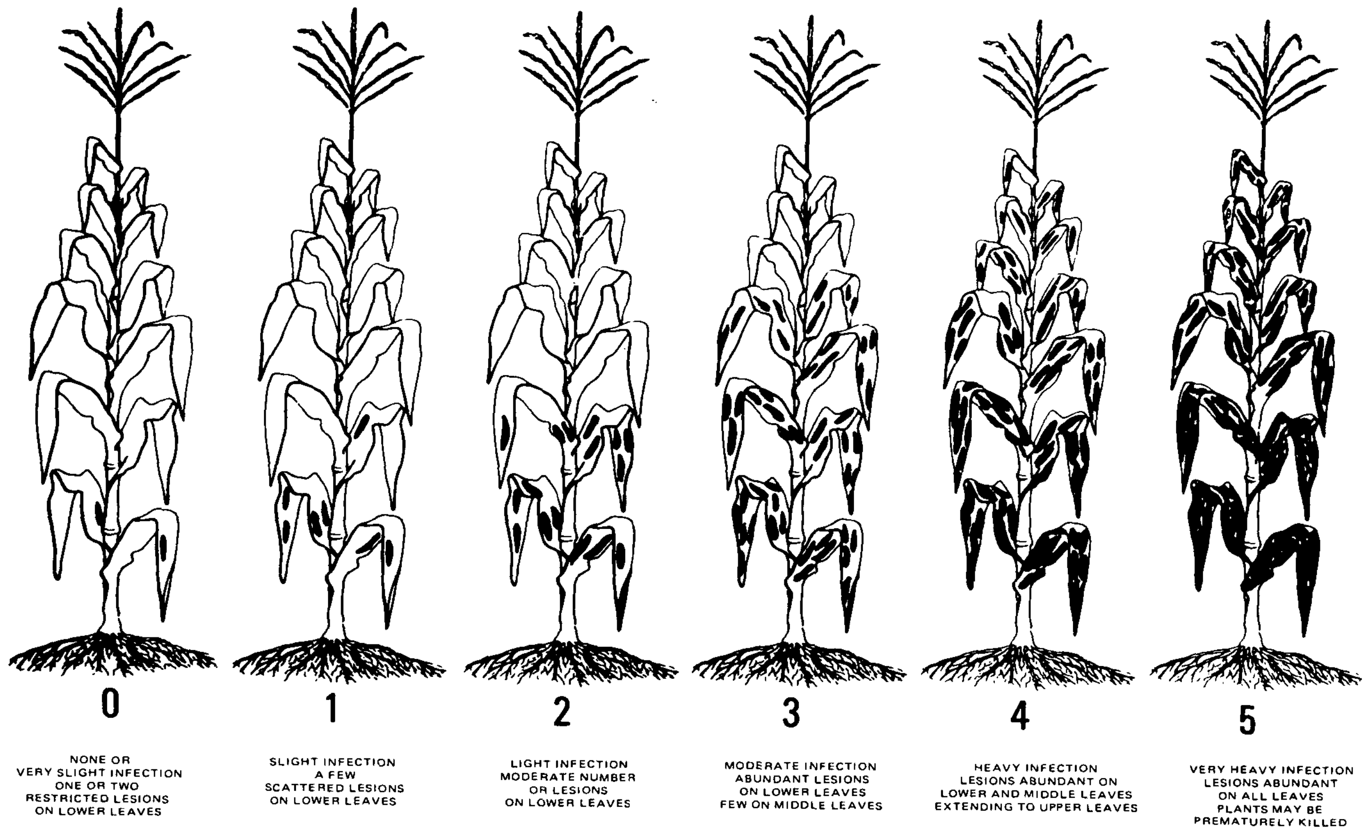



Figure 3. Scale showing the six stages of blight severity which can be identified on the ground.

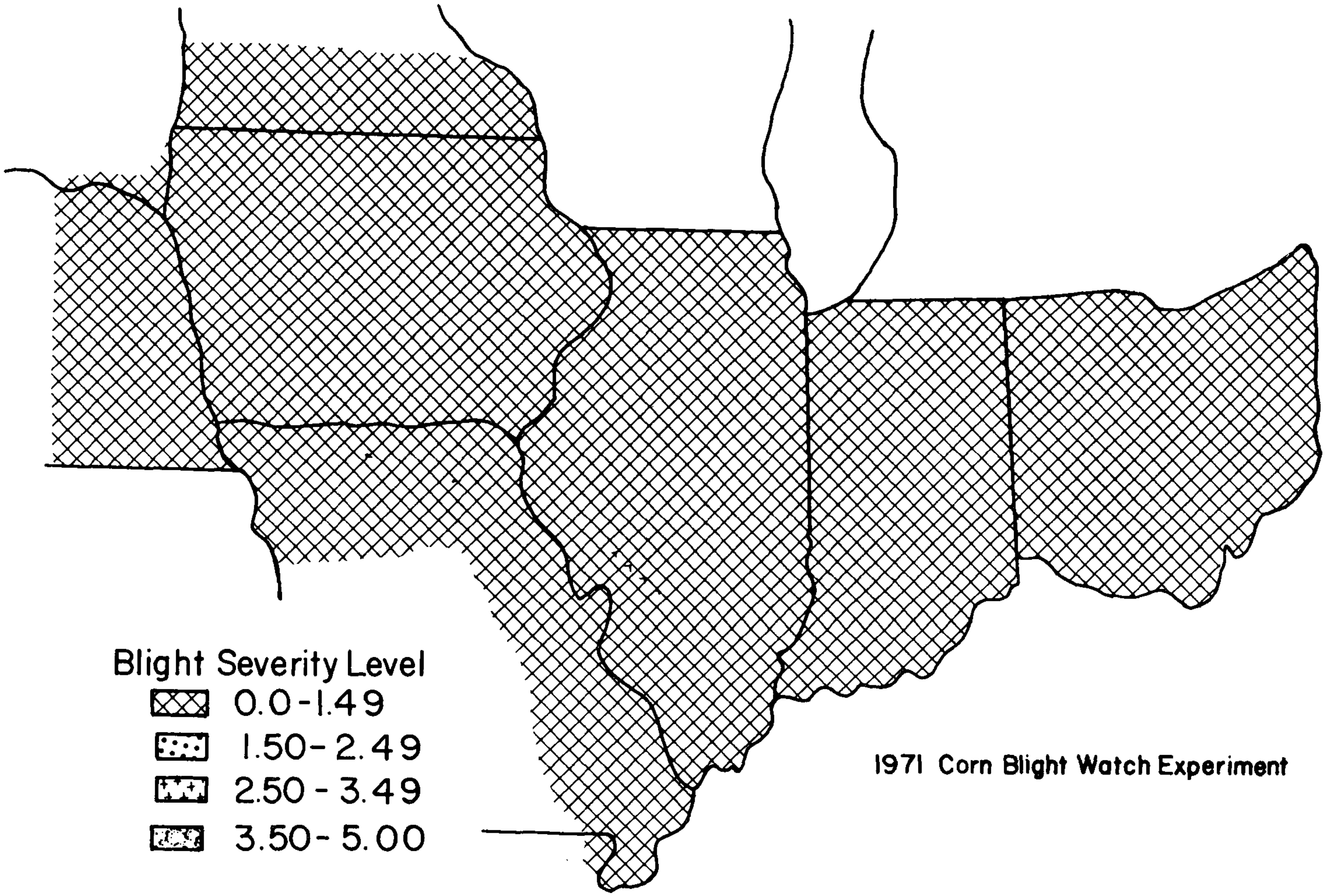



Figure 4. Average blight severity of all cytoplasm types, July 26 - 30, 1971.

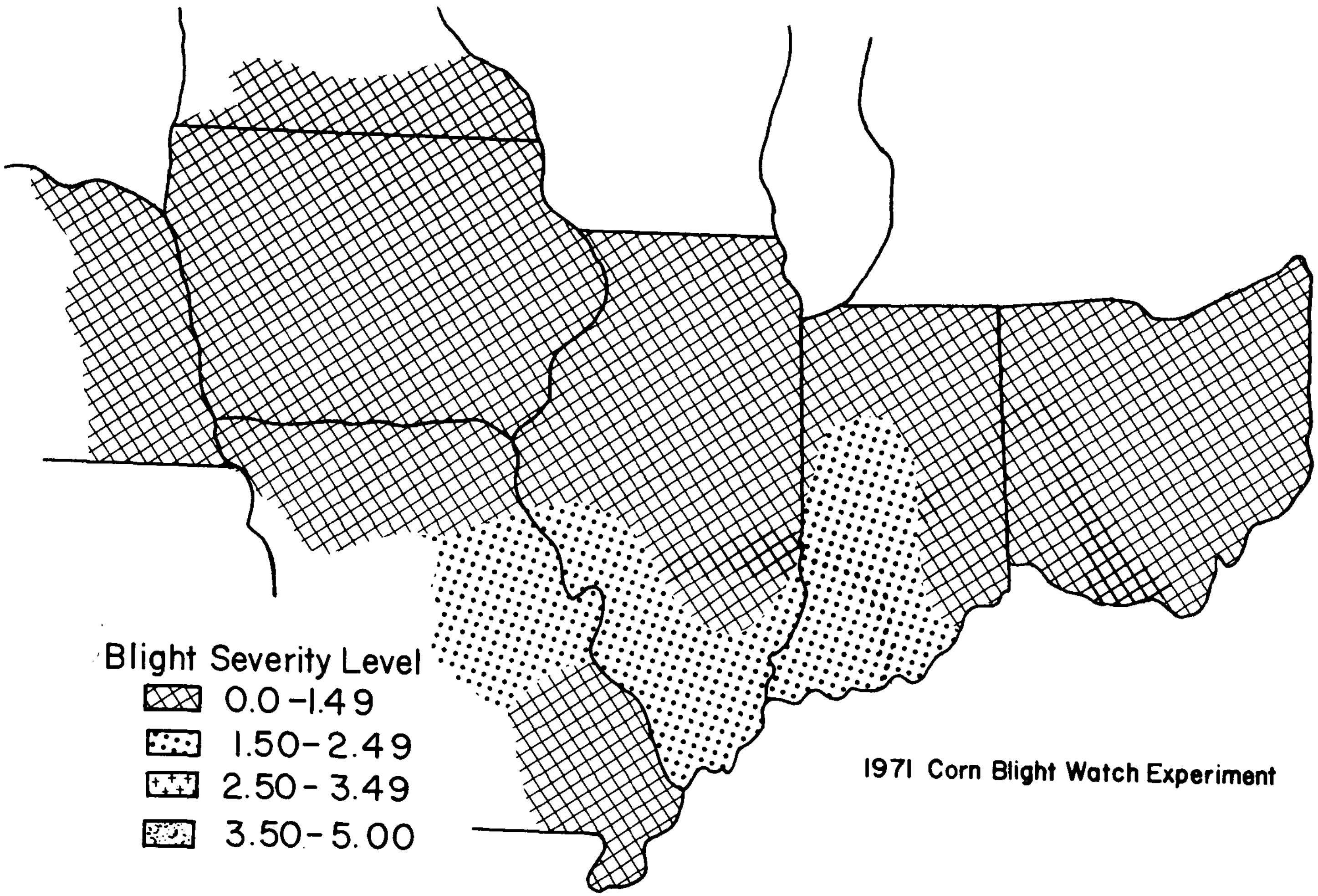



Figure 5. Blight severity of Texas male sterile cytoplasm corn, July 26 - 30, 1971.

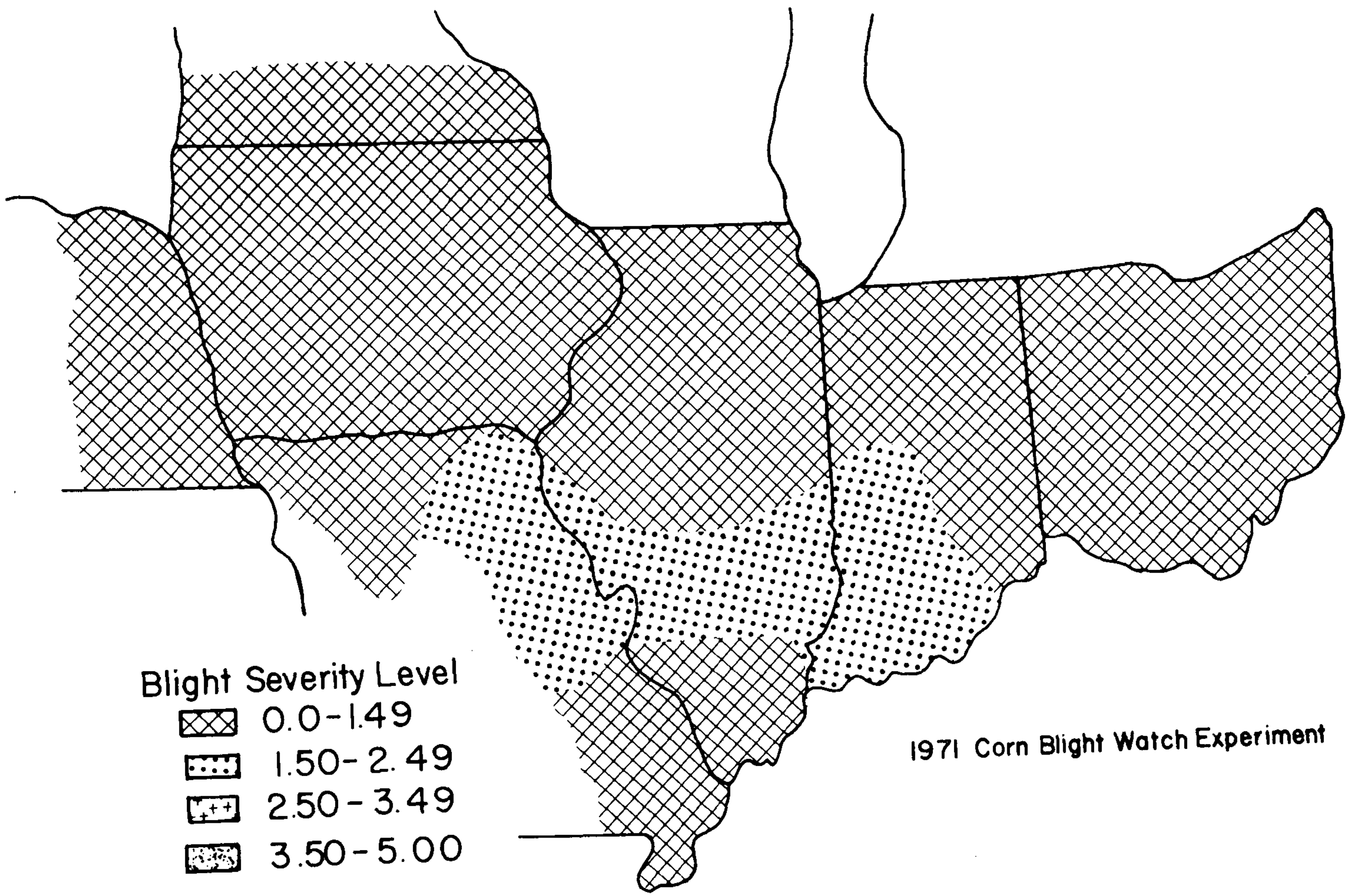



Figure 6. Average blight severity of all cytoplasm types, August 9 - 13, 1971.

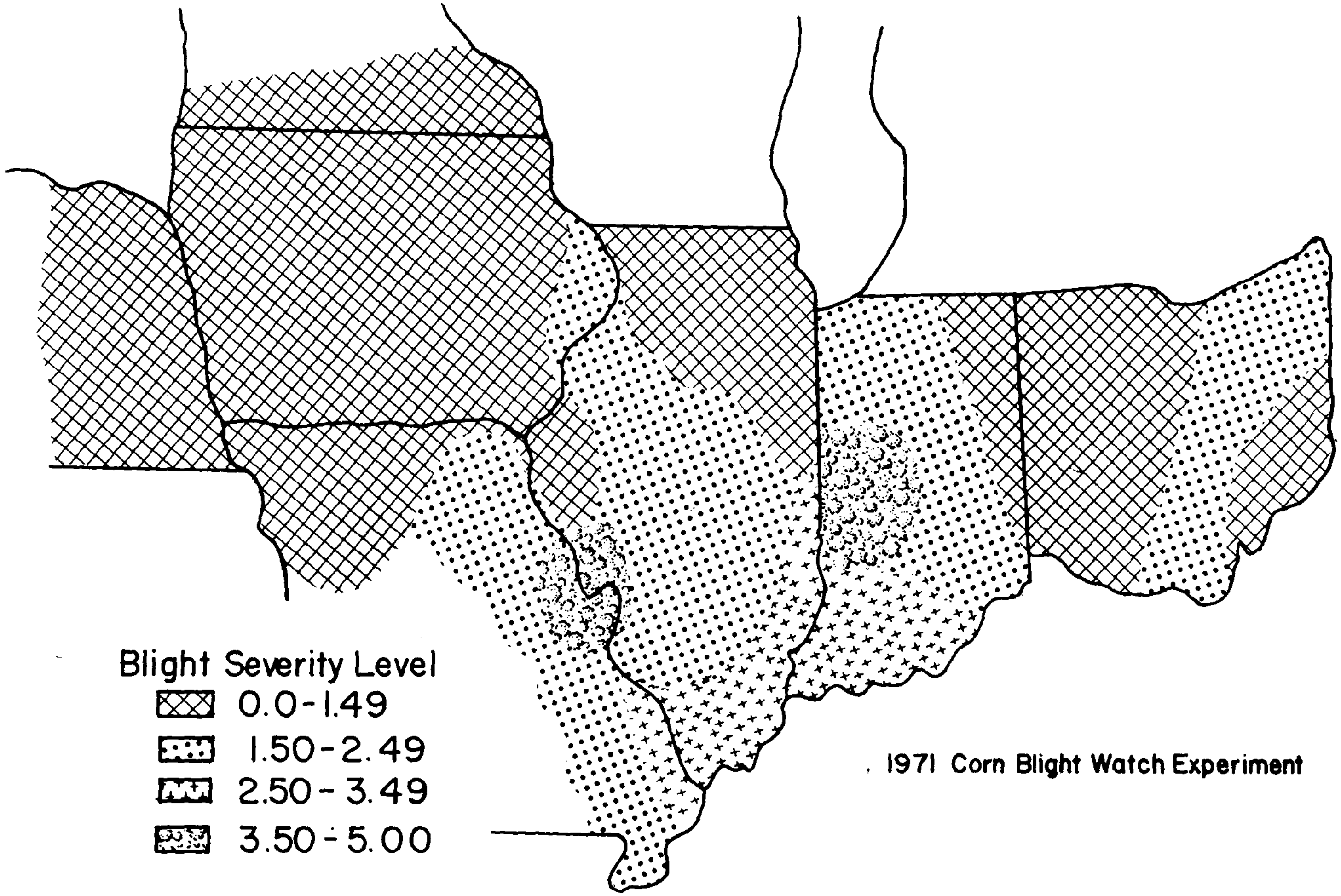



Figure 7. Blight severity of Texas male sterile cytoplasm corn, August 9 - 13, 1971.

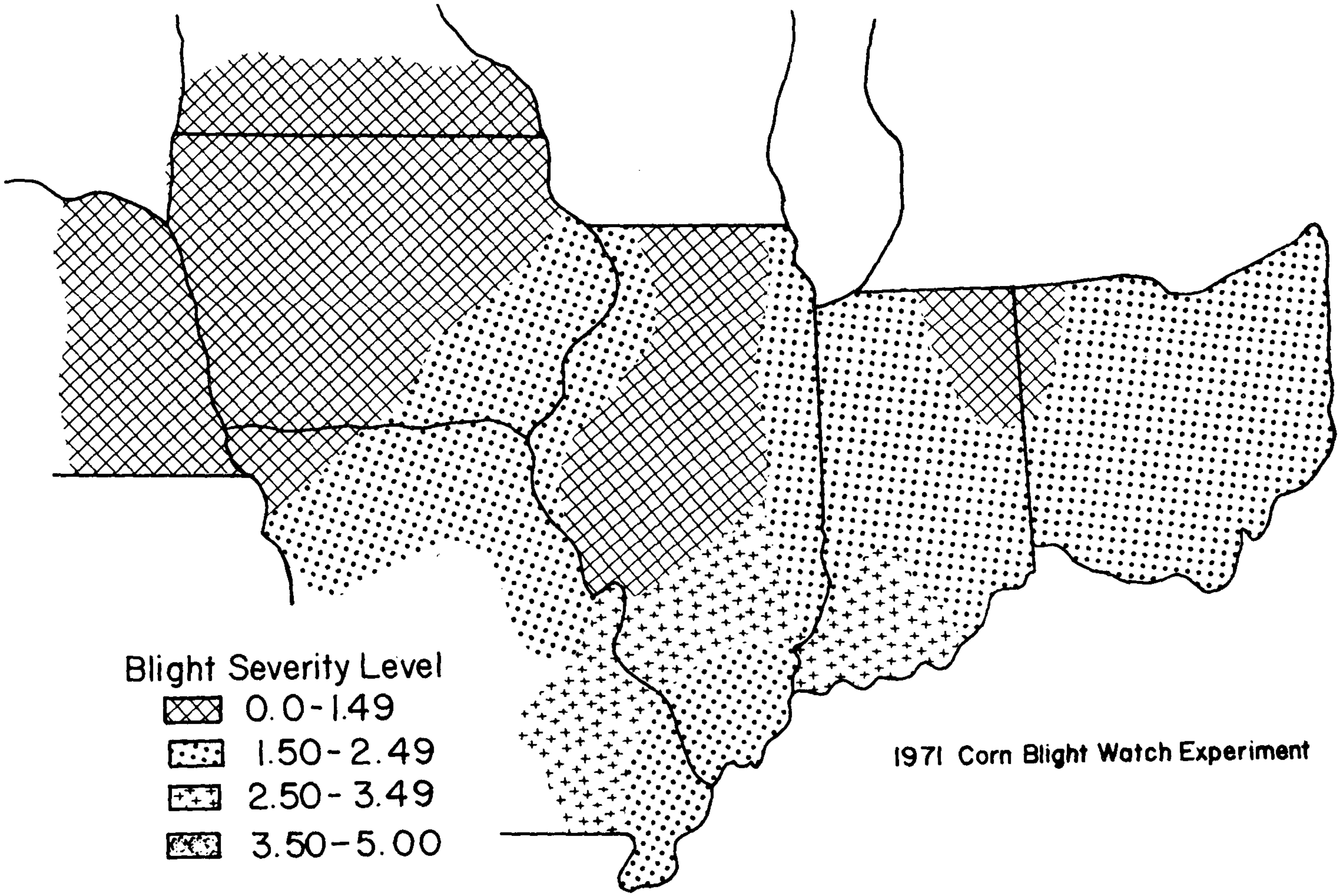



Figure 8. Average blight severity of all cytoplasm types, August 23 - 27, 1971.

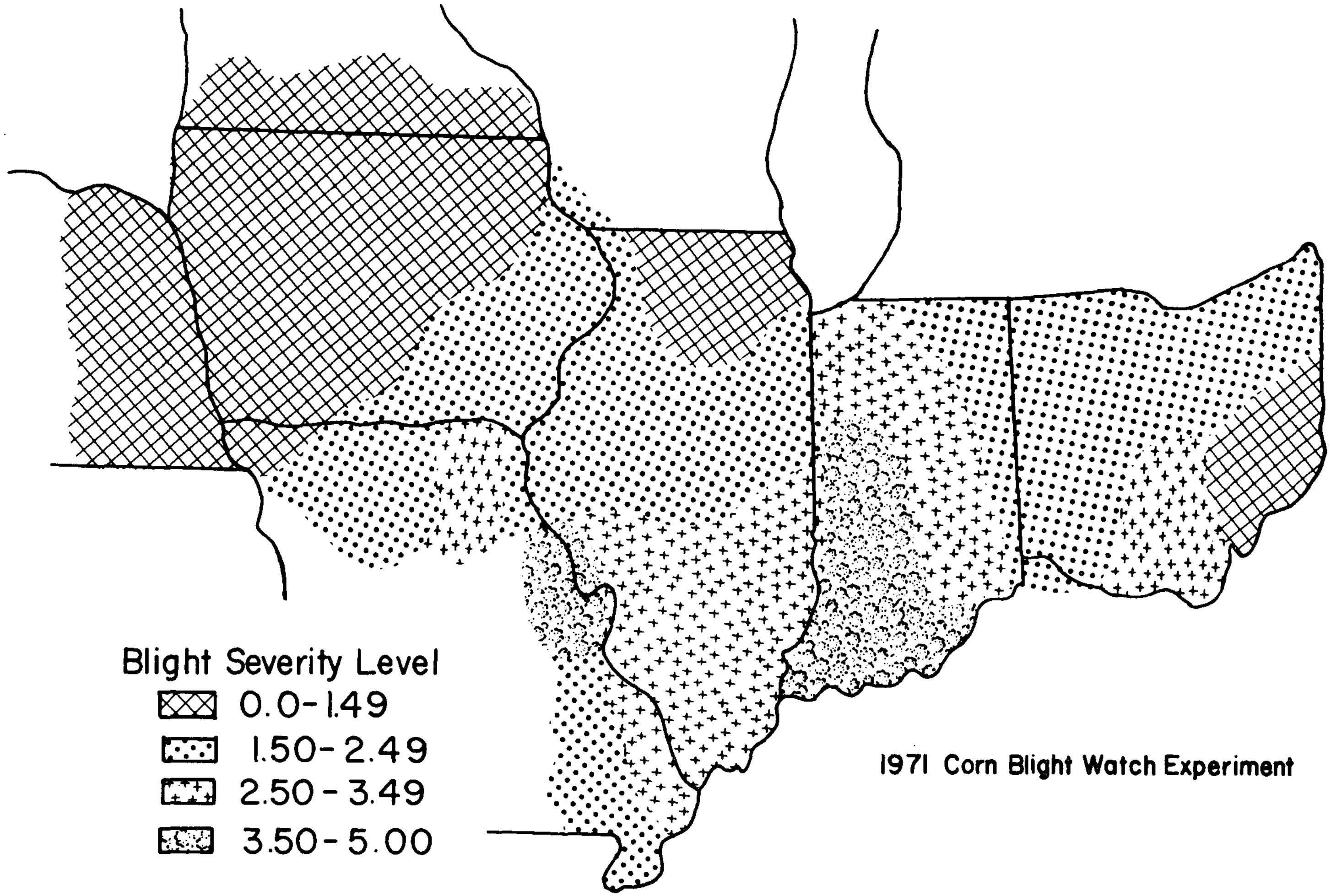



Figure 9. Blight severity of Texas male sterile cytoplasm corn, August 23 - 27, 1971.

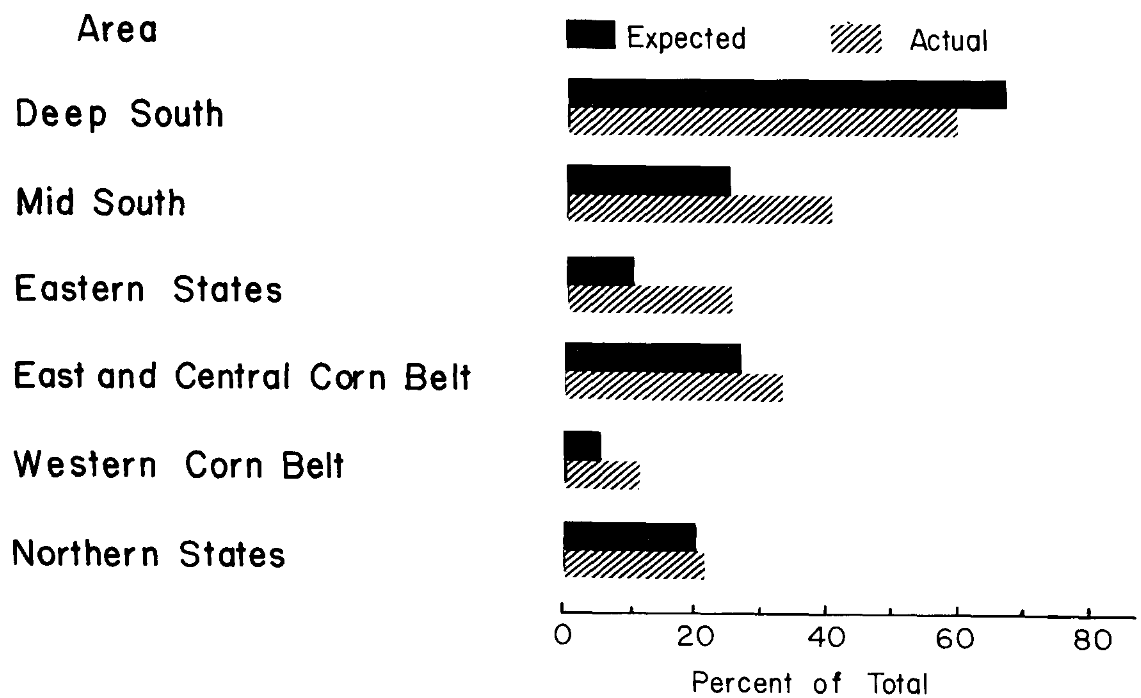



Figure 10. Comparison by geographic area of expected and actual proportion of normal cytoplasm seed planted in 1971.

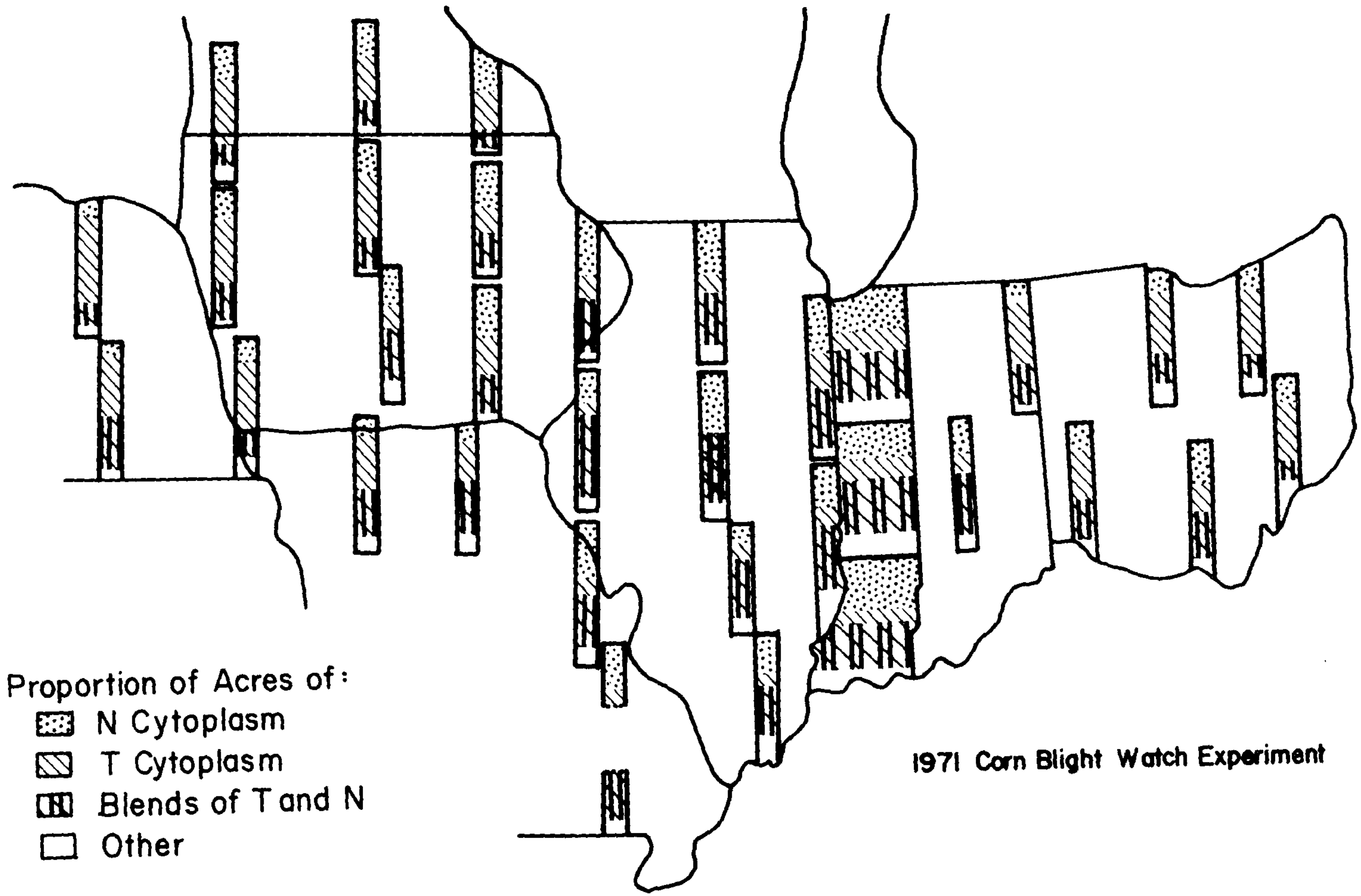



Figure 11. Distribution of corn cytoplasm types by geographic area in the Corn Belt in 1971. The highest proportions of resistant types were planted in the eastern Corn Belt.

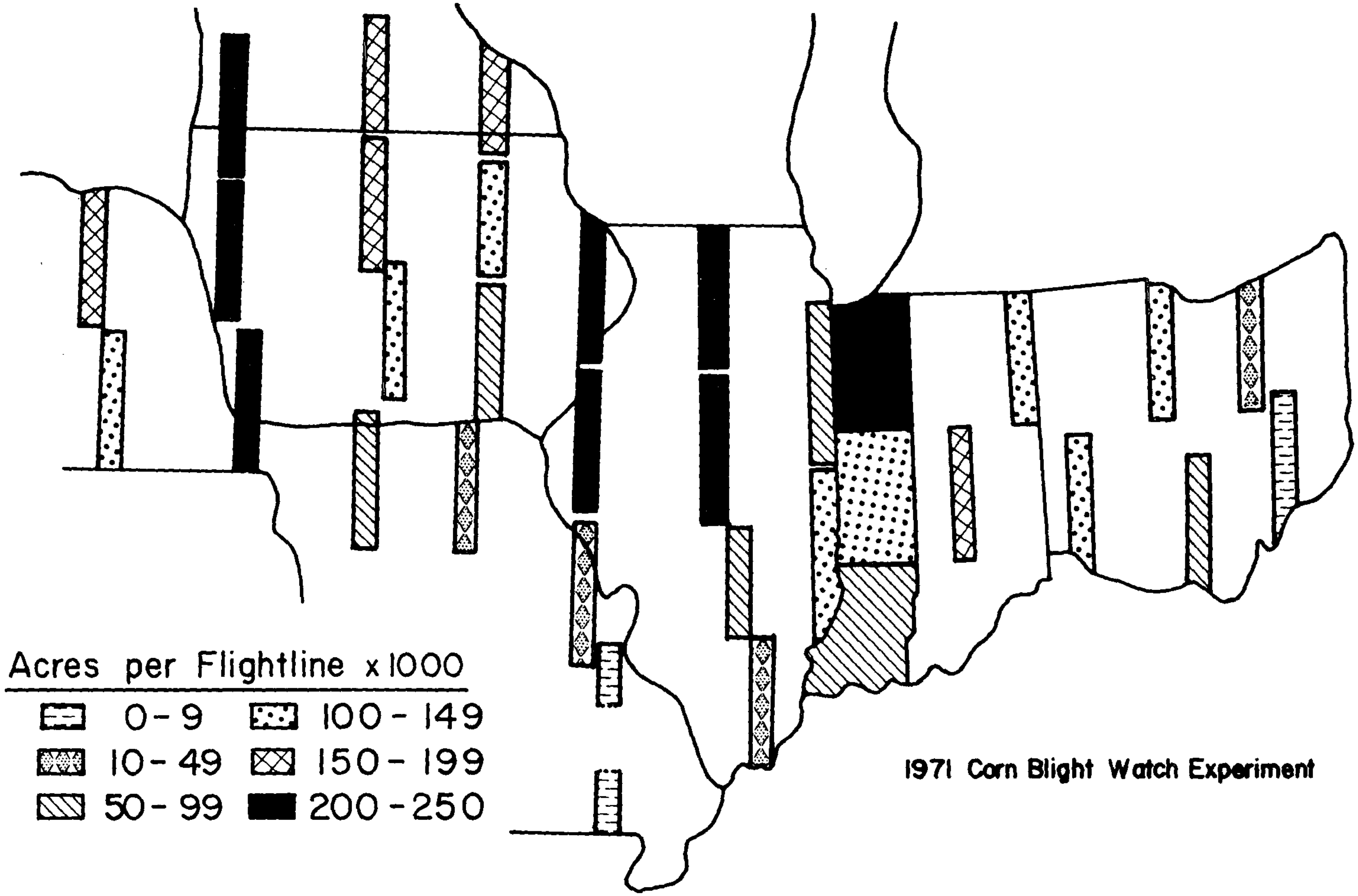



Figure 12. Density of corn acres in the experiment test area.

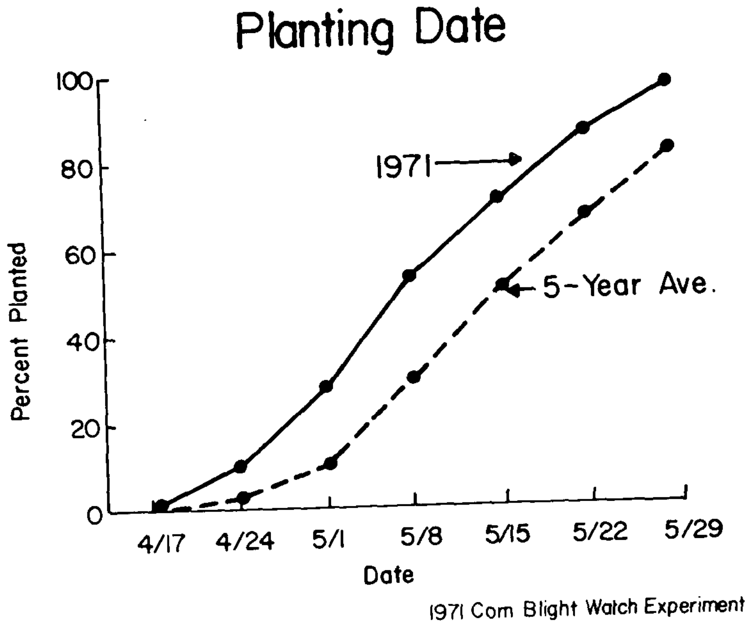



Figure 13. Favorable spring weather enabled farmers to plant the 1971 corn crop 10 days to two weeks earlier than normal.

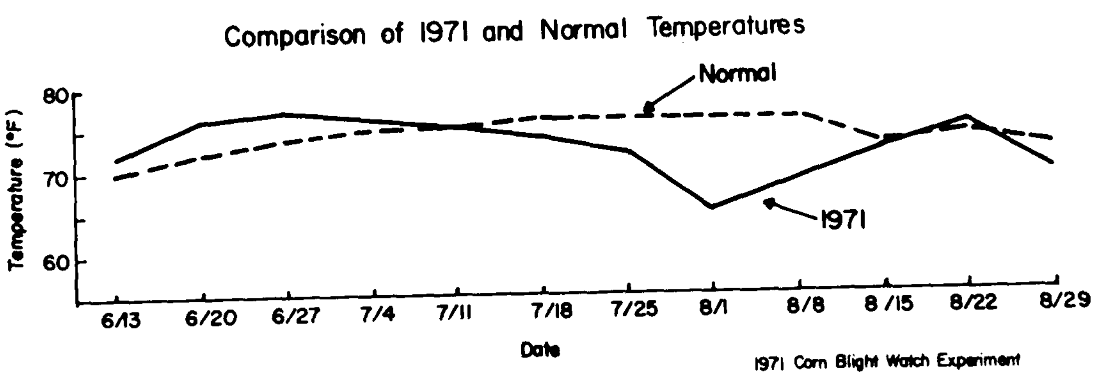



Figure 14. Above-normal temperatures in June and early July were nearly ideal for corn growth. Below-normal temperatures from mid-July to mid-August greatly retarded further blight development and were favorable for high corn yields.

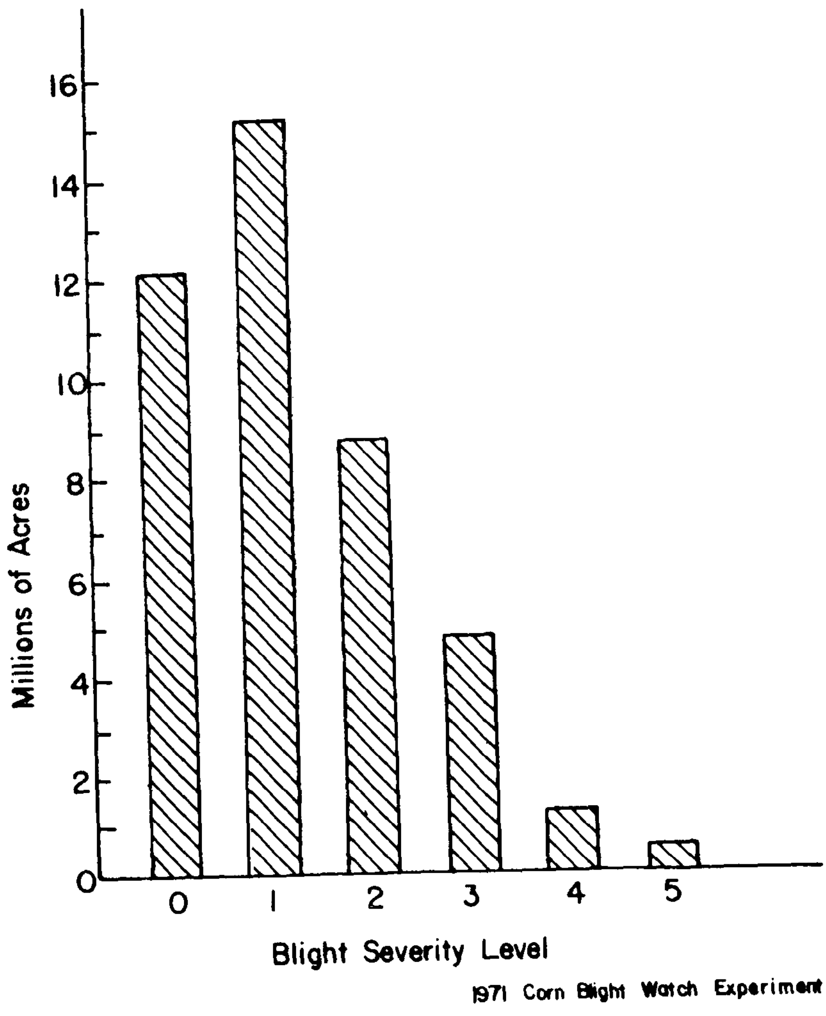



Figure 15. Number of acres in each blight severity class in the Corn Belt, August 23 - 27. At this time the crop was nearing maturity and further blight development would have little effect on yields.

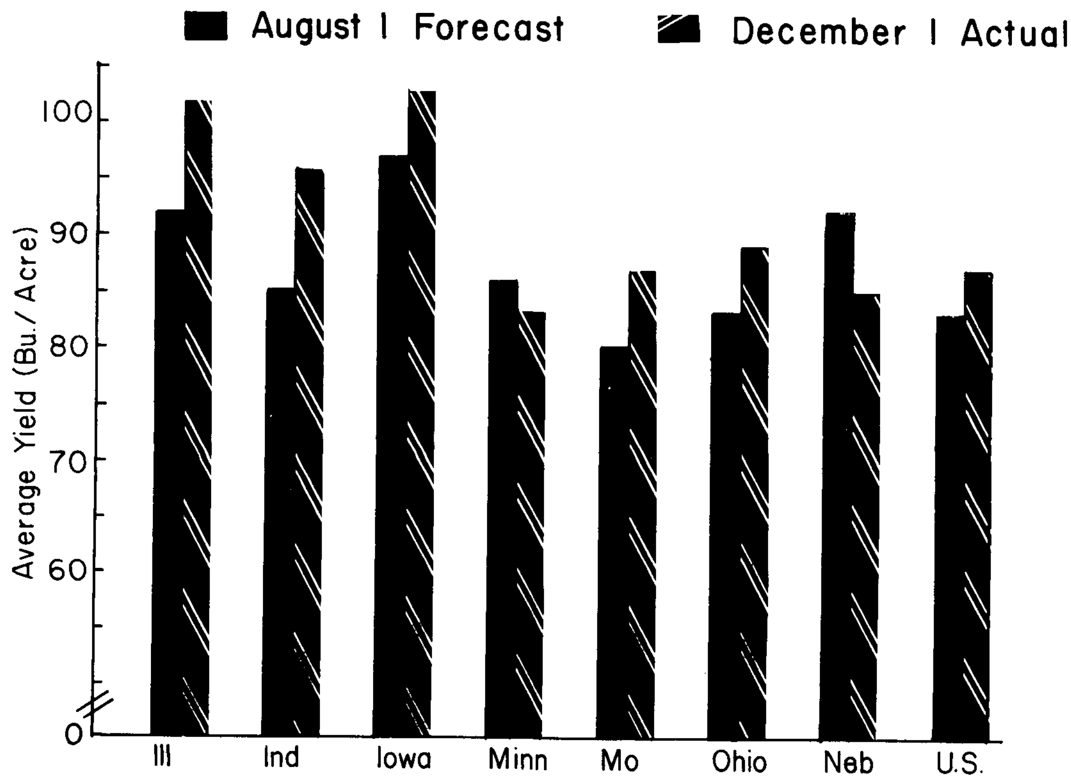



Figure 16. With favorable weather for corn and restricted blight development, record high corn yields were produced in 1971.

125-19

N72-29418



SECTION 126

# CORN BLIGHT REVIEW - SAMPLING MODEL AND GROUND DATA MEASUREMENTS PROGRAM

by

Richard Allen
Statistical Reporting Service
United States Department of Agriculture
Washington, D. C. 20250

The study area for the experiment covering portions or all of seven states included over 60 percent of the nation's corn acreage. The sampling plan involved the selection of the study area, determination of the flightline and segment sample design within the study area and determination of a field sample design. Initial interview survey data consisting of crop species acreage and land use was collected by county ASCS personnel. On all corn fields, additional information such as seed type, row direction, population, planting date, etc. were collected. From this information, sample corn fields were selected to be observed through the growing season on a biweekly basis by County Extension personnel.

## INTRODUCTION

The sampling model for the Corn Blight Watch Experiment involved the (1) selection of a study area, (2) determination of a segment (test site) sample design and (3) determination of a sample design for selecting fields. In addition, decisions were made on the amount of and type of ground data to collect. The experiment was an unprecedented data collection venture in terms of the type of data required from ground observations.

One of the first decisions made by the Executive Committee was that ground data would be able to stand on its own. Thus, the ground data would serve a dual purpose. First, ground data measurements would provide the basic training sets for photo interpretation and multispectral scanner analysis. Secondly, the ground data measurements would be collected such that meaningful estimates could be made from ground data alone and provide a basis for evaluating remote sensing performance.

The approach used in designing the sampling and ground data models cannot be stressed too highly. It is quite likely that the sampling decisions and the ground data from the Corn Blight Watch

Experiment will not fit any other regional remote sensing venture, but the techniques involved in determining the Corn Blight Watch plan will apply.

A systems analysis approach was used in designing the Corn Blight Watch sampling model and ground data program. Decisions on ground data were never divorced from the impacts that those decisions would have on remotely sensed data. Sampling decisions were not independent of data collection decisions, etc.

Each decision was made by first defining the objectives for that aspect of the program. What was the goal for that aspect? What information or result was desired? How did that aspect function in meeting the overall objectives of the experiment? How would the data collected be used?

Defining objectives seems like a logical and simple step, but many projects (both research and operational) are planned and completed without the objectives being fully defined. Data collected is then often incomplete and improper for analysis. It takes great forethought and perseverance to define objectives clearly at the planning stage.

Once the objectives for an aspect of the model had been defined, the resources available were itemized. In general, the resources used in the experiment were manpower and aircraft.

The constraints on the program and the resources were then considered. Perhaps the greatest constraint in the experiment was time. A large number of people could be made available, but for only a day or so at a time, for example. The desire for monitoring of the blight situation on a biweekly visit placed quite a restriction on data collection.

Once the objectives, resources and constraints had been defined, alternatives were drawn up and decisions made. In defining alternatives, people with expertise in that particular aspect were contacted for advice and opinions. Plant pathologists were contacted about the disease itself. People involved in planning large scale interview and field surveys were contacted about data collection forms and techniques. Aircraft people were contacted since the ground data collection had to be consistent with aircraft data gathering capabilities.

The results of this systems approach was an integrated model for sampling and data collection. For example, initial interview data from farmers provided not only the basis for selection of sample test fields, but provided auxiliary information for remote sensing interpretations.

Because individual farm operators were to be interviewed, approval of the Office of Management and Budget (OMB) was required. The survey plan, interview questionnaire and field observation forms were submitted to OMB and approved. The entire process from first planning sessions to presentation of a complete package to OMB was completed in about six weeks (mid-February to April 1).

## SELECTION OF TEST AREA

The first decision in designing the data collection model was the selection of a test area for the experiment. An overall objective of the experiment was to detect development and spread of Southern Corn Leaf Blight (SCLB) over the Corn Belt. However, the Corn Belt is not a rigidly geographic area, but instead is a descriptive term applied to the states which provide considerable acreages of corn for grain. The states in the Corn Belt vary depending on the user of the term.

Thus, the Corn Belt had to be defined. The objectives considered in this determination were to (1) include as much of the nation's corn acreage as possible, and (2) provide as wide east-west and north-south coverage as possible.

The main resources available were assumed to be one RB-57 aircraft and manpower enough to collect data in approximately 200 segments (test sites). An additional resource was considered to be an available sampling center which could select the sample of segments.

The constraints on the size of the test area were (1) number of administrative units (states) involved and (2) desired precision of estimates from collected data. The larger the number of administrative units the greater the amount of time that would be needed for training and length of training time would be critical. Manpower and aircraft resources did not limit the size of the test area in themselves, but they did limit the amount of data which could be collected. Given that only so much data could be collected, precision of estimates would depend upon the size of the area sampled.

Alternatives for selection were defined in terms of corn acres and geographic location. At the time of test area selection, prospective planting estimates by states were available in a release by the Crop Reporting Board of the Statistical Reporting Service, United States Department of Agriculture (USDA). These figures are shown in Table I for the 12 states originally considered as possibilities: Iowa, Illinois, Minnesota, Nebraska, Indiana, South Dakota, Ohio, Missouri, Wisconsin, Michigan, Kansas and Kentucky.

In addition, the most recent estimates of corn acres harvested for grain were plotted by county and by crop reporting district for all states that might be considered in the Experiment. (Crop reporting districts are geographic groupings of counties within states which are used in the Statistical Reporting Service, USDA estimating program. Most of the states in the "Corn Belt" area are divided into nine crop reporting districts).

It was first decided to include counties in the test area only if a whole crop reporting district was included. Also, the minimum number of crop reporting districts in a state which could be included was set at two. These two decisions meant that an additional administrative unit (state) would not be added to the project for the sake of only a few counties with considerable corn acreage.

The test area decided upon includes all of Ohio, Indiana, Illinois and Iowa, the eastern crop reporting districts of Nebraska, the southern crop reporting districts of Minnesota and the northern and eastern crop reporting districts of Missouri. The portions of Nebraska, Minnesota and Missouri included in the test area were expected to account for at least 67 percent of the corn acreage for grain in each state.

This test area was expected to include at least 60 percent of the nation's corn acreage for grain in 1971, based on farmers intentions to plant. Table II gives the current estimates of harvested acreage of corn for grain and production in the test area.

The test area provided an east-west magnitude of nearly 900 miles and north-south magnitude of nearly 400 miles. If SCLB would enter the Corn Belt from the south as was believed in 1970, the eastern Missouri and western Illinois areas should give early indications of blight occurrence. The Nebraska and Minnesota counties should provide indications of western and northern spread of the pathogen.

The test area selected is not a homogeneous area in terms of cropping patterns. Percent of land devoted to corn varies greatly between states and within states. Field sizes tend to be larger in the major producing counties in Iowa, Illinois, Minnesota and Nebraska than in Missouri and Ohio. A large proportion of the corn fields in Ohio and Missouri and in parts of the other states are corn fields

RD

located very close to wooded woods. Some corn fields will be located very close to or in metropolitan areas. Topography and soil types vary greatly between and within states. Thus, the remote sensing applications of the Experiment would involve interpretation of corn against many different backgrounds.

## SEGMENT SIZE DETERMINATION

Given a test area for the project, the next necessary step was determination of segment (test site) size and number of segments which could be monitored. Since SCLB should affect different cytoplasms of corn to greater or lesser extents, it was desirable to have as many different cytoplasms present within a segment as possible. In order to reduce time and travel costs, a segment should be no larger than a one-person assignment.

It was necessary to compromise statistical efficiency in order to provide the fairly large segment. Adjacent farms tend to be very homogeneous in terms of proportion of land planted to corn, varieties planted and cultural practices. Therefore, the most efficient sampling procedure for estimates from ground data alone would be to select a large sample of small segments spread throughout the test area. However, this allocation of samples could not be covered in a high altitude aircraft study without going to complete photo coverage of the test area.

Number of segments and size of segment were determined to a great extent by manpower. ASCS indicated a willingness to devote 1,000-1,500 man days to the project for field operations. It was assumed that this input might be matched by the Extension Service of the various states. If interviewing took about one week and if 7 to 8 one-day visits were to be made for field observations, about 200 segments of land could be studied.

Segment sizes from four square miles up to 12 square miles were considered. The smaller sizes would be a convenient size for interviewing. The larger sizes would provide a good number of corn fields in nearly every segment, but might require more than one week for collection of basic data in corn fields.

A rectangular, one mile by x miles, shape was assumed to be the desired shape. The rectangular shape would result in more within segment variation in cropping than would a square segment of the same area. A segment size of one mile by eight miles was tentatively adopted as the desired segment size. This provided a good compromise of ground data time requirements and expected number of corn fields per segment.

## SEGMENT SAMPLING DESIGN

The objectives in selecting the segment sampling design were to (1) represent the total area and (2) maximize the statistical precision from the number of segments.

The greatest benefit from the relatively small number of large segments which were possible would have been to draw a simple random or stratified random sample of segments from the area. Selecting 200 counties based on the square root of expected corn acres would have given a good distribution across the test area. Establishing one segment in each county would have minimized ground travel time and cost.

Such an allocation of segments was plotted but it could not be covered within the time constraints of two weeks. It was necessary, therefore, to select a sampling plan based on the aircraft limitations. In order to provide photographic coverage within a two week period, the maximum number of flightline miles was estimated to be about 4,000 miles if flightlines were 100 miles or longer and about 3,000 miles if individual lines were to be 50 miles or less.

The sampling plan was reevaluated in light of the constraints imposed by the aircraft. The two-stage (flightline and segment within flightline) procedure would limit the statistical precision of estimates from the experiment. All estimates would contain between flightline and between segment within flightline variations. Since segments within flightlines should be relatively homogeneous, the between flightline variance components would be large.

If flightlines were not needed as a stage in the sampling process, expansions of segment totals would be subject to between segment variation only. This between segment component would be larger than the between segment within flightline component, but should have lower total variance than the two-stage procedure.

In order to increase the statistical validity of at least part of the Experiment, it was decided to sample a portion of the test area in the more optimum manner. In order to accomplish this, total photo coverage was requested for a portion of the test area.

The three crop reporting districts in western Indiana were selected as the area for the more optimum sampling scheme. Many of the resources available were concentrated in this area. Since the scanner aircraft could not cover the larger area in a two-week period, all scanner flights would be made in the western Indiana area.

The experienced analysts at the Laboratory for Applications of Remote Sensing (LARS) and Willow Run Laboratories (WRL) felt that 15 segments of data would be a substantial assignment for computer analysis from each overflight. Thus, 30 segments were designated for the intensive study area, with half of the segments to be analyzed at WRL and the other half at LARS.

It was decided to sample the rest of the test area with 30 flightlines of approximately 100 mile lengths, each containing six segments. This gave a total of 210 segments (30 + 180) to be selected. The total flightline length exceeded the preliminary target of 4,000 miles, but there would be some efficiencies since western Indiana would be totally covered.

## SELECTION OF SEGMENTS

Segments in both the intensive study area and the remaining portion of the test area were chosen by accounting for all land on maps and selecting the sample of segments from the total. In the intensive study area, this process involved a process of physically assigning all land to a specific segment. All of the segments were delineated on maps and a systematic sample of 30 segments chosen.

In the portion of the test area outside western Indiana, 1:1,000,000 aeronautical charts were divided into flightlines of eight miles wide by approximately 100 miles long. A systematic sample of 30 flightlines was chosen. Each flightline was then divided into segments of size one mile by eight miles. A sample of six segments was chosen in each flightline.

In both selection procedures, nonagricultural land was excluded from the sample before segments were selected. Definite nonagricultural areas were identified and boundaries drawn in around the excluded areas. Small (less than four square miles) areas of nonagricultural land were not excluded and all questionable land was left in the sample.

In order to facilitate the scanner analysis, segments in the intensive study area were orientated north-south. They were drawn with section lines as the center of the one mile wide segments so that roads would be located down the center of the segment as often as possible. The length of these segments was also increased to 10-12 miles in order to guarantee more corn fields for analysis.

The segments outside of western Indiana were mainly one mile north-south by eight miles east-west. Thus, the segments were oriented across the line of flight in order to maximize the physical distance between segments within flightlines.

The procedure of excluding nonagricultural land worked quite well considering the mapping materials that were available. Only one segment did not contain any corn fields and that segment did have other agricultural land. Some selected segments were within the metropolitan areas of cities such as Cleveland and Indianapolis, but they did contain corn fields and other agricultural land.

There were some segments in which a large portion of the segment was not agricultural. These were cases in which it was not possible to determine from maps if agricultural uses might be made of the land.

## INITIAL INTERVIEW SURVEY DATA

The objectives of the initial interview survey were to (1) identify crop or land use in each field within segments, (2) collect information on corn fields for sample selection, and (3) collect information which might be helpful in remote sensing interpretations.

Experienced photo interpreters and multispectral data analysts were contacted for suggestions for the initial interview. They were asked which characteristics of corn fields they felt would be important in image responses. Specialists in conducting large scale crop interview surveys were contacted about questionnaire content and format.

In the interview procedure adopted, each farm operator was identified and interviewed. Each of his fields was delineated on aerial photography prints and numbered. Acreage and crop or land use was recorded for every field. Nonagricultural areas within the segment were delineated, but no information from them was processed.

Additional information was collected for each corn field. Specific questions were asked about the field and its susceptibility to SCLB. These included cytoplasm of corn planted, variety of corn, whether corn was planted in the same field the previous year and if blight was apparent in corn fields the previous year. The remaining questions were intended to provide information for interpreting the appearance of each corn field on remote sensing images. These questions included date planted, width of corn row, plant population per acre, direction of corn rows and whether the field would be irrigated.

An example of the initial interview form is shown in Figure 1.

The initial interviews were conducted by personnel in the county offices of the Agricultural Stabilization and Conservation Service, USDA. These personnel were experienced in contacting farm operators and in the use of aerial photography.

All interviewers attended a one-day training school. All aspects of the survey were covered in these intensive training sessions. Four man teams from the participating agencies conducted the training schools.

Over 8,200 interviews were conducted by some 300 ASCS personnel during a 10-day period. Information of land usage and acreage was obtained for over 56,000 fields.

## SAMPLE FIELD SELECTION

The goal in selection of fields for visits during the growing season was to represent the different cytoplasms present in each segment. However, the number of fields per segment had to be limited to a number which could be visited in one day.

Eight to ten fields were felt to be a reasonable maximum number of fields for an assignment. Once units were established within a field, the field observer would be returning to the same units each time. Since detailed observations were to be made on only five plants in each of the two units in the field, it should not take long for the observations.

The strata used for sample field selection were (1) normal cytoplasm (resistant to SCLB) only, (2) Texas male sterile (susceptible to SCLB) cytoplasm only, (3) blends of normal and Texas male sterile only, (4) F-2 or openpollinated (non-hybrid) fields and (5) combinations of the other strata planted in a field plus unknown cytoplasms. This fifth stratum covered several types of fields, but (except for some fields of unknown cytoplasm) each field in the stratum had some normal cytoplasm plants and some Texas male sterile plants in the field.

The F-2 and openpollinated fields were combined in one stratum because both types did not usually occur in the same segment and both should cause some reduction in yield potential. There were not many of these fields (only about one percent of the expanded acreage) but this lower yield potential and the different susceptibility to SCLB of the two types seemed a reasonable cause for creating the separate stratum.

If two fields were selected from each stratum present, the maximum sample size for a segment would be ten fields. The maximum in most segments would be eight fields since F-2 and openpollinated fields rarely occurred.

Additional ground data was requested for the intensive area segments. Since even ten fields would be a small number of fields for training the computer, the sampling rate for the Texas male sterile and blend strata was increased to three fields each in these segments. This new maximum of 12 fields per segment could not take into account all of the possible blight situations in a segment, but it was an absolute limit on the workload which could be assigned.

In crop yield studies, sample fields are often selected on a probability proportional to field acreage basis. Thus, every acre in the sampling frame has the same chance of selection. This type of sample selection is referred to as self-weighting.

Most studies of SCLB in 1970 concluded that level of infection was generally fairly uniform within fields. Since the main purpose of the Corn Blight Watch Experiment was to study blight infection, not corn yield, fields were selected on an equal probability basis. That is, each field within a stratum in a segment had the same chance of selection, regardless of size.

Equal probability selection will result in more small fields being selected than would probability proportion to acreage selection. The larger number of small fields was expected to create some problems for scanner analysts in locating fields and training the computer, but it was felt to be the best way to study the effects of SCLB.

Most of the field observations were to be made by personnel of the Extension Services within each state. The State Extension Services work closely with farm operators providing information about various aspects of farming.

It was envisioned that nearly all sample corn fields might be needed for training by photo interpreters and scanner analysts. There would be few, if any, fields with ground data left for testing of classification results. Therefore, an additional sample of fields was selected in 24 segments. These additional fields were worked by ASCS personnel. These additional fields could be used for testing by individual interpreters and analysts, and they would provide insurance that adequate ground data was being collected in at least part of the segments in case more data was needed for training.

The 24 segments were chosen to give geographic coverage cross the test area and within individual states. Five segments were selected in Iowa, Illinois and Indiana, three segments in Ohio and two segments in Minnesota, Nebraska and Missouri. Segments were requested in particular areas of each state. Specific segments were chosen on basis of number of corn fields and availability of ASCS county personnel for the field observations.

The extra fields were selected from only the normal cytoplasm, Texas male sterile cytoplasm and blend field strata. Two fields were selected from each of the above strata, provided two or more fields remained in the strata after the original sample had been selected. The original sample fields were excluded and a systematic sample of two fields was selected from the remaining fields.

Table III summarizes the number of fields selected in individual segments. Numbers in all cases are original number of fields selected.

As indicated in Table III, only one segment did not have any corn fields and just one segment contained a single corn field. Since desired sample size per stratum was two fields, the selection of an odd number of fields such as seven, nine or 11 indicates that only one field was available in some strata.

One criticism of the field selection procedure was that a very high number of small fields were selected. The small fields were particularly a problem in the intensive study area where the multi-spectral scanner analyses were performed. The analysis techniques used involve either preparing a tape loop from each training field or outlining the field boundaries on a visual display. A very small field may be too small to effectively use for training purposes.

It is important for several reasons to not ignore these small fields, however. In some applications of remote sensing the small fields might actually be different than large fields. For example, different cultural practices might be used in large fields. Secondly, to improve remote sensing technology the small field problems must be solved. Some crops for which crop identification might be desired such as tobacco are commonly grown on small acreages. In addition, as scanner systems go to higher altitudes to more efficiently cover larger areas, large fields will then be small in terms of number of data points.

Another reason for not ignoring small fields is that even for corn a considerable portion of the crop might be grown in small fields. The corn field size results from the initial interviews in the intensive study area of western Indiana are presented in Table IV.

The percent of total corn fields column of Table IV indicates the approximate distribution of field sizes expected when sampling with equal probabilities of selection. The percent of total corn acres column indicates the expected sample distribution if probability proportional to corn acres selection had been used. These distributions are only approximations since small or large fields might be concentrated in certain segments.

One alternative to the equal probability or probability proportional to size selection would be to select large and small fields at different sampling rates. However, that procedure would not have been possible in this survey because of the constraints of estimating for 5 strata and keeping sample field allocation to a maximum of 10-12 fields at the same time. Splitting each strata into large and small fields and selecting at least two fields in order to calculate variances would have doubled the sample size.

## FIELD OBSERVATION DATA

The Field Observation Form was designed to obtain four types of information to describe the conditions in two randomly selected units within the sample field:

1. The amount of vegetation present.

2. The presence and severity of Southern Corn Leaf Blight and other leaf diseases.

3. The presence and severity of other crop stresses.

4. Crop maturity and other information which might affect photography and scanner imagery.

To obtain estimates of the amount of vegetation present, the following items were measured or counted: row width, number of plants in 30 feet of row, number of leaves per plant on five plants in the unit, and length and width of the leaf at the seventh node of each sample plant. From these items plant population and a leaf-area index could be calculated.

Data for estimating Southern Corn Leaf Blight infection were obtained in two ways: (1) Placing each of the five sample plants in unit 1 and 2 into a blight severity class from zero (none) to five (very severe), and (2) counting the number of lower and upper leaves with lesions and estimating the percentage of lower and upper leaf area covered by lesions. The first rating by the field observer was called a subjective rating. Pictures and descriptions of the different severity classes were included in a disease detection handbook which was prepared. An "objective" blight severity rating using the information in (2) was calculated as an aid to the photo interpreter.

Other stresses such as drought, extreme weediness, lodging, hail damage, insect damage, other diseases and nutrient deficiency were identified. Specific comments describing the kind and extent of stress were requested of the field observers to aid in the interpretation of the sample fields on photographs and scanner imagery.

Other information which might aid remote sensing interpretation included number of plants with tassels, stage of maturity and uniformity of the field. The field observer compared the randomly selected units with the portion of the field surrounding the units in answering whether the units were representative of the field.

Figure 2 is an example of the field observation form designed for the Corn Blight Watch. The same form was used throughout the season except for the questions on width of rows and number of plants.

The basic assumptions underlying the field observation procedure were that data should be repeatable and consistent. If two people were sent to the same field independently, the results should be the same. Also, observations taken throughout the season should be of the same plants. Thus, variation in observation results will be done to physiological changes, not sampling variations.

In order to have repeatable and sequentially consistent data, certain plants or certain areas of the field must be defined and marked. Procedures were designed so that each observer would locate, define and mark units in exactly the same manner.

The desires to have good within field information and at the same time have as many fields as possible were compromised. It was decided to establish two units for observation within each sample field. Two units would allow estimation of within field variations but not greatly increase the time per field over one unit so an observer could visit several fields in one day.

Since it was important to keep definitions and procedures as simple as possible, a unit size of one row, 30 feet long was adopted. This would not give any indication of within unit (between row) variation but it would mean that length measurement would be needed only once in each unit. The fairly long length of 30 feet should ensure a sufficient number of plants for observation in most units.

In order to ensure that each observer would establish units similarly, a random location of units were specified. However, to reduce the workload within a field, the location of the first unit in a field was limited to no more than 200 rows and 200 paces from the starting corner. In addition, the second unit was defined to be 30 rows and 30 paces beyond the first unit. Thus, the two units would be located a distance apart but would not require two completely separate location steps.

Individual plant observations were made on the first five plants of each unit. The total unit was used for determining plant population, other stress factors and representativeness of the units. Plant population was collected on only the first and last field visit in order to reduce within field time requirement.

One suggestion which was expressed was to use the six level (0 to 5) blight severity scale as the only indication of SCLB intensity. This would greatly reduce the within field time requirement. However, this would have supplied very little information on actual intensity of blight. Plants can vary greatly in terms of numbers of blight lesions, amount of leaf area covered by lesions and even location of SCLB on the plants and still be in the same severity class. Severity of infection can change considerably on a plant but it might still be classified as the same severity class.

Recording of some specific measures of blight infection would allow a better comparison of blight condition from one period to another. The measures would not have to be very precise; the important thing would be a good indication of relative blight condition. Recording some specific information on blight infection would also allow analysts to interpret differences in fields which have the same subjective blight rating.

Other individual plant observations were blight lesions on stalks, ears or ear shoots with blight lesions and ears with evidence of ear rot. These items were included to give indications of severity of blight infection.

Most field observations were made on Monday or Tuesday of the designated survey week. If weather prevented observations on the intended date, they were made as soon as possible afterwards. Some observations were delayed longer or missed on a particular mission if the field observer was "rained out" on the regular observation date and could not fit the observations into his schedule soon afterwards.

## PREHARVEST YIELD FORM

There was considerable interest as the growing season developed in collecting of yield information from each field. It was hoped that this information give some indications of the effects of SCLB and corn yields during 1971. A Form B-9 was designed to collect yield information for each field.

Yield information was not included as part of the original data collection plan for a number of reasons. First of all, the sampling procedures used were designed to study incidence of blight and were not optimum sampling procedures for making yield estimates. It could not be predicted before the season what the extent of blight would be in 1971 and whether yield information would be of value or not.

Also, if yield information did turn out to be important, procedures for collecting this information could be better prepared during the season when the blight situation could be observed.

Figure 3 is a copy of the B-9 form. Its format follows that of the other field observation forms as much as possible.

The preharvest yield visit was to be made as close to the actual date of harvest as possible. One of the indications of damage on the B-9 form was number of ears of corn already on the ground. For this item to be meaningful, observations had to be made close to harvest.

All harvested ears were mailed to LARS for laboratory analysis. This analysis consisted of inspection for damage, weighing of grain and moisture testing.

Table I.--1971 Prospective acreages of corn for grain, by states 1/

| State | Indicated acres | Percent of 35 states 2/ | Cumulative percent |
|---|---|---|---|
| | 000 | | |
| Iowa | 11,841 | 16.89 | 16.89 |
| Illinois | 10,442 | 14.90 | 31.79 |
| Minnesota | 6,254 | 8.92 | 40.71 |
| Nebraska | 6,145 | 8.77 | 49.48 |
| Indiana | 5,418 | 7.73 | 57.21 |
| South Dakota | 3,628 | 5.18 | 62.39 |
| Ohio | 3,507 | 5.00 | 67.39 |
| Missouri | 3,301 | 4.71 | 72.10 |
| Wisconsin | 2,907 | 4.15 | 76.25 |
| Michigan | 2,003 | 2.86 | 79.11 |
| Kansas | 1,672 | 2.39 | 81.50 |
| Kentucky | 1,167 | 1.67 | 83.17 |
| 12 State total | 58,285 | 83.17 | --- |
| 35 State total | 70,088 | --- | --- |

1/ Prospective plantings, January 25, 1971, Statistical Reporting Service, U.S. Department of Agriculture.
2/ The 35 states accounted for 98.3 percent of 1970 U.S. planted corn acreages.

Table II.--Acreage and production of field corn for grain in the Corn Blight Watch test area, 1971 1/

| State | Acreage: Harvested acreage | Acreage: Percent of United States | Production: Bushels harvested | Production: Percent of United States |
|---|---|---|---|---|
| | 000 | | 000,000 | |
| Iowa | 11,570 | 18.1 | 1,180 | 21.3 |
| Illinois | 10,170 | 15.9 | 1,037 | 18.7 |
| Indiana | 5,509 | 8.6 | 534 | 9.6 |
| Ohio | 3,526 | 5.5 | 314 | 5.7 |
| Minnesota | 3,936 2/ | 6.2 | 327 2/ | 6.0 |
| Nebraska | 4,004 2/ | 6.3 | 340 2/ | 6.1 |
| Missouri | 2,316 2/ | 3.6 | 204 2/ | 3.7 |
| Total | 41,031 | 64.3 | 3,936 | 71.1 |

1/ Source: Crop Production, January 14, 1972, Statistical Reporting Service, U.S. Department of Agriculture

2/ Acreage in state adjusted by proportion of acreage within the test area in 1970.

Table III.--Number of segments by sample size

| Number of fields selected | Number of segments: Seven-state area | Intensive study area | ASCS sample |
|---|---|---|---|
| 0 | 1 | | |
| 1 | 1 | | |
| 2 | 4 | | |
| 3 | 4 | | |
| 4 | 7 | | 5 |
| 5 | 4 | 2 | |
| 6 | 7 | | 19 |
| 7 | 14 | 1 | |
| 8 | 106 | | |
| 9 | 15 | 7 | |
| 10 | 17 | 13 | |
| 11 | | 4 | |
| 12 | | 3 | |
| Total.. | 180 | 30 | 24 |

Table IV.--Percent of corn fields and percent of acreage by field size: Western Indiana segments

| Field size | Percent of total corn fields | Percent of total corn acres |
|---|---|---|
| Acres | | |
| 0-9 | 33.4 | 7.3 |
| 10-19 | 30.1 | 21.2 |
| 20-29 | 15.8 | 18.8 |
| 30-39 | 8.7 | 14.5 |
| 40-49 | 4.9 | 10.6 |
| 50-59 | 2.3 | 6.0 |
| 60-69 | 1.5 | 4.7 |
| 70-79 | 0.7 | 2.7 |
| 80-89 | 0.9 | 3.9 |
| 90-99 | 0.6 | 3.0 |
| 100 and larger | 1.1 | 7.2 |

Form A

16. Have all the fields you operate inside the segment boundaries been accounted for? Yes ☐ No ☐
*(If NO, go back to Q - 1 and complete column for each missing field)*

*ASK question 17, if CORN was reported in Question 4.*

17. Will you permit us to set out two small plots in your **CORN** fields and visit them twice a month through mid-September? Yes ☐ No ☐

---

**ITEM 12: CONVERSION TABLE FOR PLANTS PER ACRE CODE**

| Inches between plants | Width of Corn Row - (inches) - Item 11: 20 | 25 | 30 | 36 | 40 |
|---|---|---|---|---|---|
| 4 | 4 | 4 | 4 | 4 | 4 |
| 6 | 4 | 4 | 4 | 4 | 4 |
| 8 | 4 | 4 | 4 | 3 | 2 |
| 10 | 4 | 3 | 3 | 2 | 1 |
| 12 | 4 | 3 | 2 | 1 | 1 |
| 14 | 3 | 2 | 2 | 1 | 1 |
| 16 | 2 | 1 | 1 | 1 | 1 |
| 18 | 2 | 1 | 1 | 1 | 1 |
| 20 | 1 | 1 | 1 | 1 | 1 |

| Code | Plants per acre |
|---|---|
| 1 | Less than 16,000 |
| 2 | 16,000 - 19,999 |
| 3 | 20,000 - 23,999 |
| 4 | 24,000 or more |

**NOTES**

UNITED STATES DEPARTMENT OF AGRICULTURE
Statistical Reporting Service
and
Agricultural Stabilization and Conservation Service

O. M. B. Number 40-S71030
Approval Expires 12-31-71

## 1971 CORN BLIGHT WATCH EXPERIMENT

### Form A - Initial Interview

| | |
|---|---|
| Form Number ................................ | 1-4 3010 |
| State ( ______________ ) | 5-6 |
| Flight Line ................................ | 7-9 |
| County ( ______________ ) | |
| Segment Number ................................ | 10-12 |
| Tract Code ( ______________ ) | 13-15 |
| Date ______________ | 17-19 |
| Starting time (Military time) ................ | 20-23 |

In 1970 Southern Corn Leaf Blight had quite an impact on corn production in the Corn Belt. It also caused concern about the availability of seed corn this spring. Because of a possible outbreak of corn blight this year, a cooperative project called the Corn Blight Watch Experiment was developed to monitor any spread across the Corn Belt and to assess levels of infestation. Information will come from periodic field visits and aerial photography during this growing season. One of the sample areas is outlined on these aerial photos.

I would like to identify your farming operation located within the boundaries on these photos. In addition, I want to record the acreage and crop or land use for each field and ask some questions about any corn fields you have planted or intend to plant this year.

______________
Enumerator

Time Interview Ended (Military time) | 24-27

Figure 1

| "Now I would like to ask question about each field you operate inside the segment boundaries". Field No. | 28-29<br>1 | 28-29<br>2 | 28-29<br>3 | 28-29<br>4 | 28-29<br>5 | 28-29<br>6 | 28-29<br>7 | 28-29<br>8 | 28-29<br>9 | 28-29<br>10 | 28-29<br>11 | 28-29<br>12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Total acres in this field ............................ | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 | 30-33 |
| *If part of field is outside segment*<br>2. Acres within segment boundaries.................. | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 | 34-37 |
| 3. Crop or land use .......................... *(specify)*<br>(If **CORN**, specify field, sweet or popcorn)<br>*(If field not yet planted, enter operator's intention.)* | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 | 38-40 |
| *Continue if any type of CORN is or will be planted in this field.* | | | | | | | | | | | | |
| 4. Acres of **CORN** planted or to be planted for all purposes.............................. | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 | 41-44 |
| 5. Acres of **CORN** intended for grain ................ | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 | 45-48 |
| 6. Date **CORN** planted or intended to be planted.... | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 | 49-51 |
| 7. *If field corn* - - Type of field corn planted *Enter Code*<br>1 - Yellow dent   3 - Flint<br>2 - White   4 - Other ______ *(specify)* | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 | 52 |
| 8. Variety (name and number) of **CORN** planted. (List all varieties if more than one) ................ | | | | | | | | | | | | |
| 9. **CORN** seed cytoplasm planted. *Enter Code*<br>1 - N (Normal)   3 - B (Blend of N&T)<br>2 - T (Texas male sterile)   4 - F-2 hybrid<br>5 - Not known | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 | 53 |
| a. If **BLEND**, what is the percent of Normal cytoplasm seed in this blend? *Enter DK if percent unknown... (percent)* | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 | 54-55 |
| 10. Type of planting pattern. *Enter Code*<br>1 - Uniform planting of one variety<br>2 - Large blocks of separate varieties within the field<br>3 - Narrow (12 ›s or less) strips of two or r varieties<br>4 - Hyb..d seed . oduction | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 | 56 |
| 11. Width of **CORN** row....................... *(inches)* | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 | 57-58 |
| :stimated plants per acre. *Enter Code*<br>1 - less than 16,000   3 - 20,000 - 23,999<br>2 - 16,000-19,999   4 - 24,000 or more<br>*If plants per acre not known, determine number of inches between plants and refer to the conversion table on page 4 for code.* | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 | 59 |
| 13. Direction of **CORN** row. *Enter Code*<br>1 - N-S   3 - NE-SW   5 - Contour<br>2 - E-W   4 - NW-SE | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| 14. Was **CORN** planted in this field last year? *Enter Code*<br>1 - Yes   0 - No | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| a. *If Yes*, was corn blight evident in this field last year? *Enter Code*<br>1 - Yes   0 - No | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 | 62 |
| 15. Acres to be irrigated this year ..................... | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 | 63-66 |

*Complete a separate column for each field located within the segment boundaries on these photo prints.*

*CONTINUE INTERVIEW ON PAGE 4.*

**Figure 1 - Continued**

UNITED STATES DEPARTMENT OF AGRICULTURE
*Statistical Reporting Service*
and
State Cooperative Extension Services

O. M. B. Number 40-S71030
Approval Expires 12-31-71

# 1971 CORN BLIGHT WATCH EXPERIMENT

## FORM B-1: Field Observation
(On or about June 15)

Corner of field entered [ ]
N W – 30
N E – 40
S E – 50
S W – 60

| | |
|---|---|
| Form Number | 3011 |
| State Code | |
| Flight Line | |
| Segment Number | |
| Tract Code (________) | |
| Field Number | |
| Flight Date | |
| Date (________) | |
| Starting Time (Military) | |
| Comparable plants | |

**UNIT LOCATION**

| | UNIT 1 | UNIT 2 |
|---|---|---|
| Number of rows along edge of field | | |
| Number of paces into field | | |

Are these the same 5 plants visited last time?

Unit 1 Yes ( ) 1 No ( ) 2

Unit 2 Yes ( ) 1 No ( ) 2

**COUNTS WITHIN 30 FOOT UNIT**

| | UNIT 1 | UNIT 2 |
|---|---|---|
| 1. Width across 10 corn row spaces ... *Feet & Inches* | | |
| 2. Number of plants in the 30 foot unit | | |

**OBSERVATIONS ON FIRST 5 PLANTS**

| | UNIT 1 *Number* | UNIT 2 *Number* |
|---|---|---|
| 3. Plants with **tassels visible beyond leaves** | | |
| 4. Plants with **blight lesions on stalks** | | |
| 5. Plants with **evidence of stalk rot** | | |
| 6. Plants with **ears** or **silked ear shoots** | | |
| 7. **Ears** or **silked ear shoots** | | |
| 8. Ears or ear shoots **with blight lesions** | | |
| 9. Ears with evidence of **kernel formation** | | |
| 10. Ears with evidence of **ear rot** | | |

– Over –

**COMMENTS:**

Figure 2

| OBSERVATIONS ON INDIVIDUAL PLANTS | UNIT 1 | | | | | UNIT 2 | | | | | TOTALS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant Number | | | | | Plant Number | | | | | Unit 1 | Unit 2 |
| **Lower 7 Nodes** | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | | |
| 11. Number of leaves | | | | | | | | | | | | |
| 12. Number of leaves with lesions | | | | | | | | | | | | |
| 13. Percent of leaf area affected with lesions | | | | | | | | | | | | |
| **Upper Nodes (Above the first 7 nodes)** | | | | | | | | | | | | |
| 14. Number of leaves | | | | | | | | | | | | |
| 15. Number of leaves with lesions | | | | | | | | | | | | |
| 16. Percent of leaf area affected with lesions | | | | | | | | | | | | |
| **Measurement And Infestation** | | | | | | | | | | | | |
| 17. Height of plant (until tassel stage) ...... *Inches* | | | | | | | | | | | | |
| 18. Length of leaf at 7th node ...... *Inches* | | | | | | | | | | | | |
| 19. Midpoint width of leaf at 7th node ...... *Inches* | | | | | | | | | | | | |
| 20. Degree of blight infestation *(Use Code 0, 1, 2, 3, 4 or 5. See Field Manual for detailed explanations.)* ...... Code | | | | | | | | | | | | |

*Enter code for each plant, then enter code totals in the Total cells for Item 20 ONLY.*

*Complete Item 21 if Item 7, Unit 1 is greater than zero.*

| | EAR NUMBER | | | | | TOTAL |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| 21. Stage of maturity of 5 ears or silked ear shoots before Unit 1, Row 1. — Code | | | | | | |

2 – Pre-blister
3 – Blister
4 – Milk
5 – Dough
6 – Dent
7 – Mature

22. Observation of other stress factors present in the 30 foot sample row. *(Specify in detail in Comments.)*

1 – None
2 – Lodging
3 – Drought
4 – Extremely weedy
5 – Insects
6 – Hail
7 – Disease other than SCLB
8 – Nutrient deficiency
9 – Other stresses *(Specify)* ______________________
______________________

Unit 1 *(Codes)* [ ]

Unit 2 *(Codes)* [ ]

23. Are the two sample units representative of the conditions in the area surrounding the units, considering corn blight, condition of stand, other damage, etc.? ...... Yes – 1 No – 2 *Code* [ ]

If No, explain ______________________
______________________
______________________
______________________

24. Copy total of infestation codes, Item 20, for each unit on the Field Kit envelope and CHECK ☐

25. CHECK ☐ if an infected corn leaf sample was sent to the State Laboratory.

Enumerator ______________________

Ending Time (Military) [ ]

Figure 2 - Concluded

# 1971 CORN BLIGHT WATCH EXPERIMENT

## FORM B-9: Pre Harvest Yield Determinations

Corner of field entered [ ] NW-30 NE-40 SE-50 SW-60

UNIT LOCATION

| | Unit 1 | Unit 2 |
|---|---|---|
| Number of rows along edge of field ....... | | |
| Number of paces into field .............. | | |

| | |
|---|---|
| Form Number ............... | 3019 |
| State Code ................ | |
| Flight Line ............... | |
| Segment Number ............ | |
| Tract Code(__________).... | |
| Field Number .............. | |
| .............. | |
| Date(____________)....... | |
| Starting Time(Military).... | |
| Comparable Plants ......... | |

Are these the same 5 plants visited last time?

Unit 1 Yes ( ) 1 No ( ) 2

Unit 2 Yes ( ) 1 No ( ) 2

---

| | Unit 1 Number | Unit 2 Number |
|---|---|---|
| **COUNTS WITHIN 30 FOOT UNIT** | | |
| 1. Ears attached to plants .............................. | | |
| 2. Ears on ground in unit .............................. | | |
| **OBSERVATIONS ON FIRST 5 PLANTS** | | |
| 3. Plants with stalk rot .............................. | | |
| 4. Ears harvested from first 5 plants .................. (Harvest all ears with grain) | | |
| 5. Ears with ear rot .............................. | | |

6. Place ears in separate bags for each unit and attach completed ID tag. (Check)

| Unit 1 | Unit 2 |
|---|---|
| | |

| | | |
|---|---|---|
| 7. Cytoplasm type. Enter Code ......................... | | |

1 - Normal
2 - Texas male sterile
3 - Blend
4 - F-2 variety
5 - Not known

Enumerator ______________________ Ending Time (Military) [ ]

Figure 3

N72-29419



SECTION 127

# AIRCRAFT DATA ACQUISITION

By

Ronald K. Blilie
Earth Observations Aircraft Program Office
NASA Manned Spacecraft Center
Houston, Texas

## INTRODUCTION

NASA Manned Spacecraft Center supported the 1971 Corn Blight Watch Experiment by acquiring remote sensor data with the dedicated use of the RB57F and the University of Michigan C47. See Figures 1 and 2.

Within the Earth Observations Aircraft Program Office, the experiment was known as the Corn Blight Project. The Project was organized into 3 phases based on the mission objectives and imagery required.

The specific objectives of the Project were first to acquire black and white photography with the RB57F to provide enlarged prints of each test segment. This was termed Phase I of the Project and took place in April 1971. These prints were to be sent to the Department of Agriculture to prepare an initial survey of the size and location of all crop fields and other land uses within each test segment.

Then, in May, the RB57F was to obtain color infrared photography while the C47 obtained multispectral scanner data for soils background information. This was termed Phase II. Finally, the aircraft were to collect color infrared photography and multispectral scanner data over their respective test segments repetitively throughout the growing season. This was known as Phase III and extended from mid-June through September. Phase II and III imagery was to be sent to Purdue-LARS.

## MISSION REQUIREMENTS

The aerial coverage for the RB57F included extensive areas of Ohio, Indiana, Illinois, Iowa, and portions of Minnesota, Nebraska, and Missouri (Figure 3). Two hundred and ten test segments were defined along 38 flight lines. The dimensions of each test segment was approximately 1 x 8 statute miles.

Approximately 3800 flight line miles of data were to be flown during Phase I and Phase II as well as bi-weekly during Phase III. Each flight line was independent except in western Indiana where eight parallel and overlapping flight lines provided contiguous coverage of an area defined as the Intensive Study Area. The thirty test segments located in the Intensive Study Area were overflown by both aircraft during Phase II and bi-weekly during Phase III. Phase I flights were flown at 50,000 feet to provide a convenient scale for subsequent enlargements. Phases II and III were flown at 60,000 feet for optimum aircraft endurance and sensor coverage.

Data to be acquired by the RB57F during Phase I was Aerographic Type 2402 black and white photography to be provided to the USDA in the form of 24" x 35" paper prints enlarged to a scale of 1:20,000. Aerochrome infrared type 2443 color infrared imagery was to be acquired by the RB57F during Phase II. Duplicate positive transparencies and color prints were to be provided to LARS. Color infrared film was also to be used during Phase III from which duplicate positive transparencies were to be provided to LARS. All RB57F data was acquired using metric cameras with a 9-1/2" format.

Delivery of processed Phase III imagery to LARS was required with minimum delay to permit analysis of photographic imagery in conjunction with ground observations.

## RB57F MISSION PLANNING AND OPERATIONS

Planning the RB57F portion of the project was similar to the planning of most previous RB57F missions with two major exceptions. These exceptions were data quality and data delivery.

Color infrared imagery obtained from previous RB57F missions was often nonuniform in exposure within each frame due to several factors including sun angle and atmospheric effects. Nonuniformity also occurred from frame to frame due to sun angle and scene brightness changes. This exposure nonuniformity made analysis difficult when the interpreter was dependent upon subtle tonal differencies. To reduce the exposure nonuniformity, changes were made to camera operation and processing techniques. These efforts, while not eliminating the problem, did result in improved data products. The north-south flight line orientation, while not selected to improve data quality, did permit optimum use of photographic overlap.

A single emulsion batch of color infrared film was obtained to reduce tonal variations anticipated if more than one emulsion batch was used during the Project. Tonal quality and infrared sensitivities have been found to vary between emulsion batches of the same type film causing undesirable tonal variations due to film characteristics.

Two problems occurred with the selected infrared film. Early in the Phase III, LARS detected an abnormal spotting condition on the color IR imagery. The defect was termed "cyan spotting" because the mottled appearance of the imagery was determined to be caused by a defect in the cyan layer of the emulsion. The cyan spots occurred randomly and made analysis of the imagery difficult. The cause of the defect has not been completely isolated, however, a change in manufacturing techniques appears to have provided a temporary solution. During the Project, supplemental film was flown to overcome the cyan spotting problem.

In addition to the cyan spotting problem, the selected color IR film lacked adequate range in infrared tonal variations. In other words, the film appeared too red or "hot". This problem, also, was eliminated with the use of the supplemental film.

Timely delivery of the data to LARS presented a difficult problem. A data management plan was prepared in order to meet the required delivery dates while minimizing the impact to ongoing programs. Data was flown by jet courier aircraft from the field to MSC where it was processed. Data schedules were generally met. An overall average of 10 days was required from exposure until delivery to LARS. Changes in procedures were required midway through the project to meet the desired delivery. This involved shipment of the processed film to LARS by direct airline flights to Indianapolis where a LARS representative picked up the film.

Weather is frequently a deciding factor in planning aircraft remote sensing missions. The Corn Blight Project made greater use of long range weather planning guides, such as "The Aerial Photographer's Clear Day Map" from the Manual of Color Aerial Photography, than most other missions in order to estimate the scope of coverage that should be attempted. Day to day mission operations were conducted with the assistance of an onsite meteorologist who monitored weather conditions and was prepared to advise the aircrew on the most suitable test site areas. While no attempt was made to compare actual versus forecast weather, the success of the data acquisition indicates that both long and short term weather forecasts are essential to mission planning and operations.

A factor that increased the operational flexibility of the RB57F and directly affected the success of the mission was the use of a standard sensor configuration. This eliminated sensor configuration changes in day to day operations and permitted data acquisition limited only by weather conditions, film capacity, and aircraft endurance.

In summary, the RB57F efforts resulted in the completion of 85% of the required coverage with less than 30% cloud coverage affecting the imagery. Fifty-four flights were flown over the Corn Belt. Four Hundred hours of flight time were expended on the Corn Blight Watch which is approximately 2/3 of the annual RB57F flight time allocation. Thirty percent of the available mission time was lost due to unsuitable weather, 20% was lost due to unscheduled maintenance, and 5% was lost due to scheduled maintenance. A 50% utilization factor is probably a good planning figure for future missions under similar conditions.

As many of the investigators are well aware, the Corn Blight Project resulted in the cancellation of five previously planned RB57F missions and 19 test sites. However, 12 test sites were flown on a contingency basis during the Project.

## C47 MISSION PLANNING AND OPERATIONS

The University of Michigan C47 was also dedicated to the 1971 Corn Blight Watch Experiment. The C47 provided Phase II and Phase III coverage of the 30 test segments within the Intensive Study Area (Figure 4) with the 12 channel multispectral scanner, and supplemental photography. Phase II coverage was coincident with the RB57F Phase II operations. Phase III operations began in late June and continued bi-weekly until in early October. The 30 test segments were flown individually at 5,000 feet AGL.

Of the 30 test segments within the Intensive Study Area, 15 were analyzed by LARS and the other 15 by Willow Run Laboratories. The original analog tapes containing the LARS test segments were delivered to LARS the day they were flown along with the supplemental film.

Operational criteria was established which would provide acceptable multispectral scanner data. These criteria specified that visibility at the flight altitude must be at least 6 miles with less than 30% cloud cover above the aircraft and less than 15% below the aircraft. The minimum acceptable sun angle was 50° although this limit would not be possible to meet later in the mission. These criteria proved to be satisfactory, however, an additional constraint was added later in the mission. It was determined that an excessive aircraft drift angle was unacceptable due to excessive image distortion. A limit of 15° drift angle was imposed to reduce the image distortion to acceptable levels.

In summary 98.4% of the sample areas were satisfactorily completed by the C47. One hundred and fourteen flight hours were expended. Use of the C47 in the 1971 Corn Blight Watch Experiment resulted in the cancellation of five previously planned missions.

## CONCLUDING REMARKS

In conclusion the project was different than previously planned missions in duration, coverage, and sensor configuration. The wide areal coverage and single sensor configuration did provide flexibility in mission operations that greatly contributed to mission success.

This project provided a unique opportunity for review of the data on a timely basis permitting sensor corrections to be made and evaluated in the field.

The Project also provided a excellent prelude to future support of complex aircraft and spacecraft missions.

RF

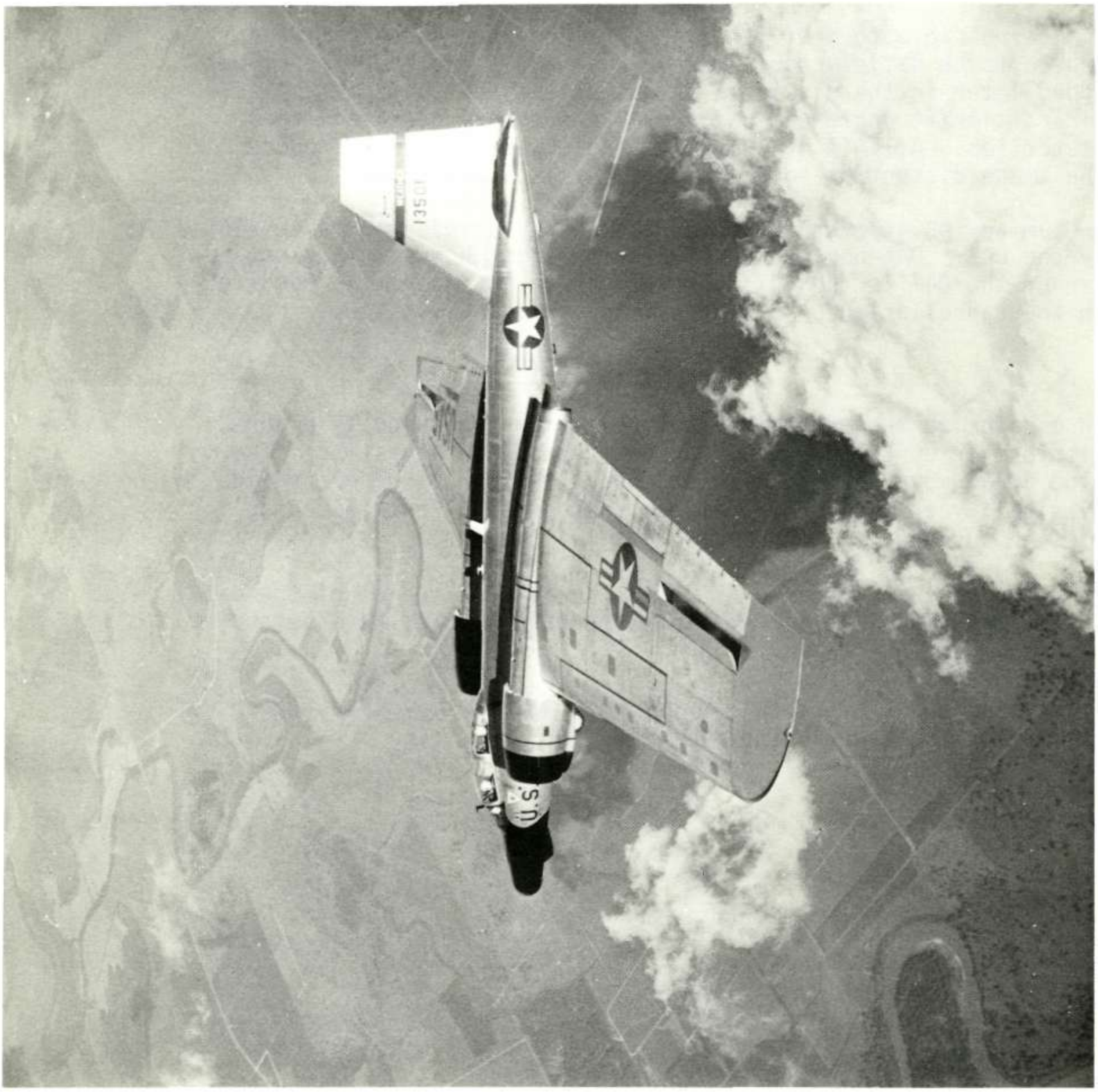


FIGURE 1 - NASA/USAF RB57F

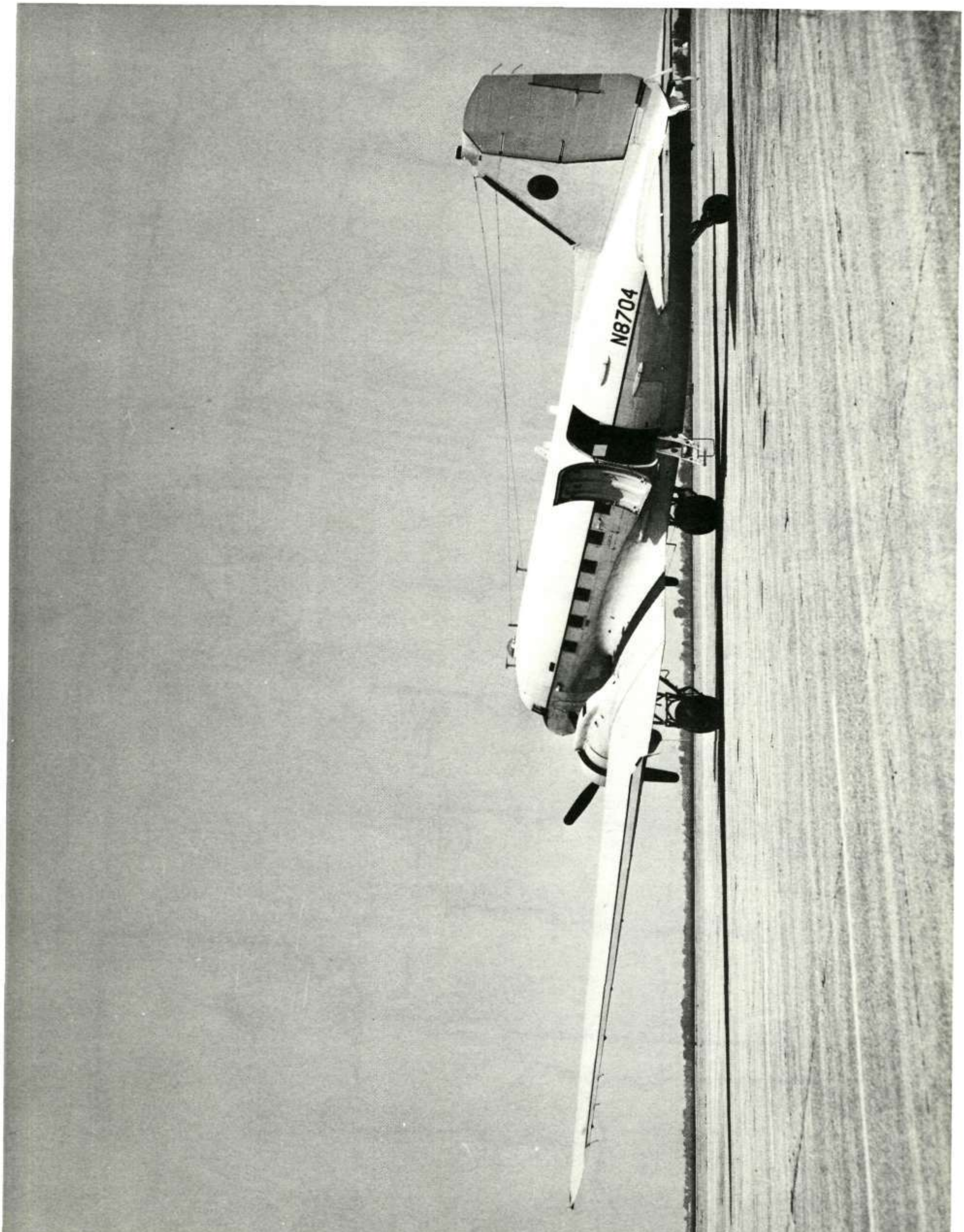



FIGURE 2 - UNIVERSITY OF MICHIGAN
C47

# CORN BELT TEST SITE

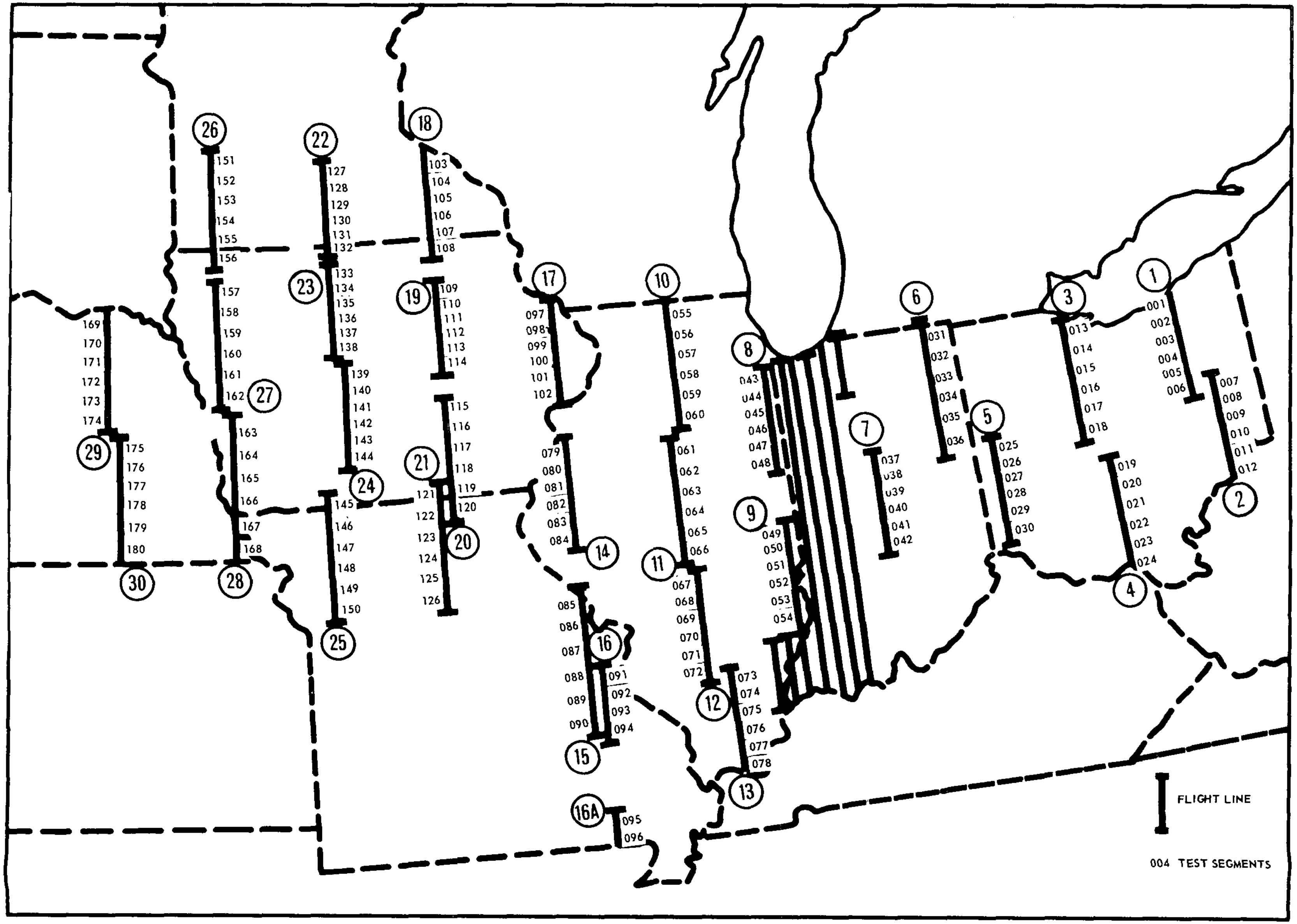



FIGURE 3 - CORN BELT TEST SITE

127-8

# INDIANA
# INTENSIVE STUDY AREA

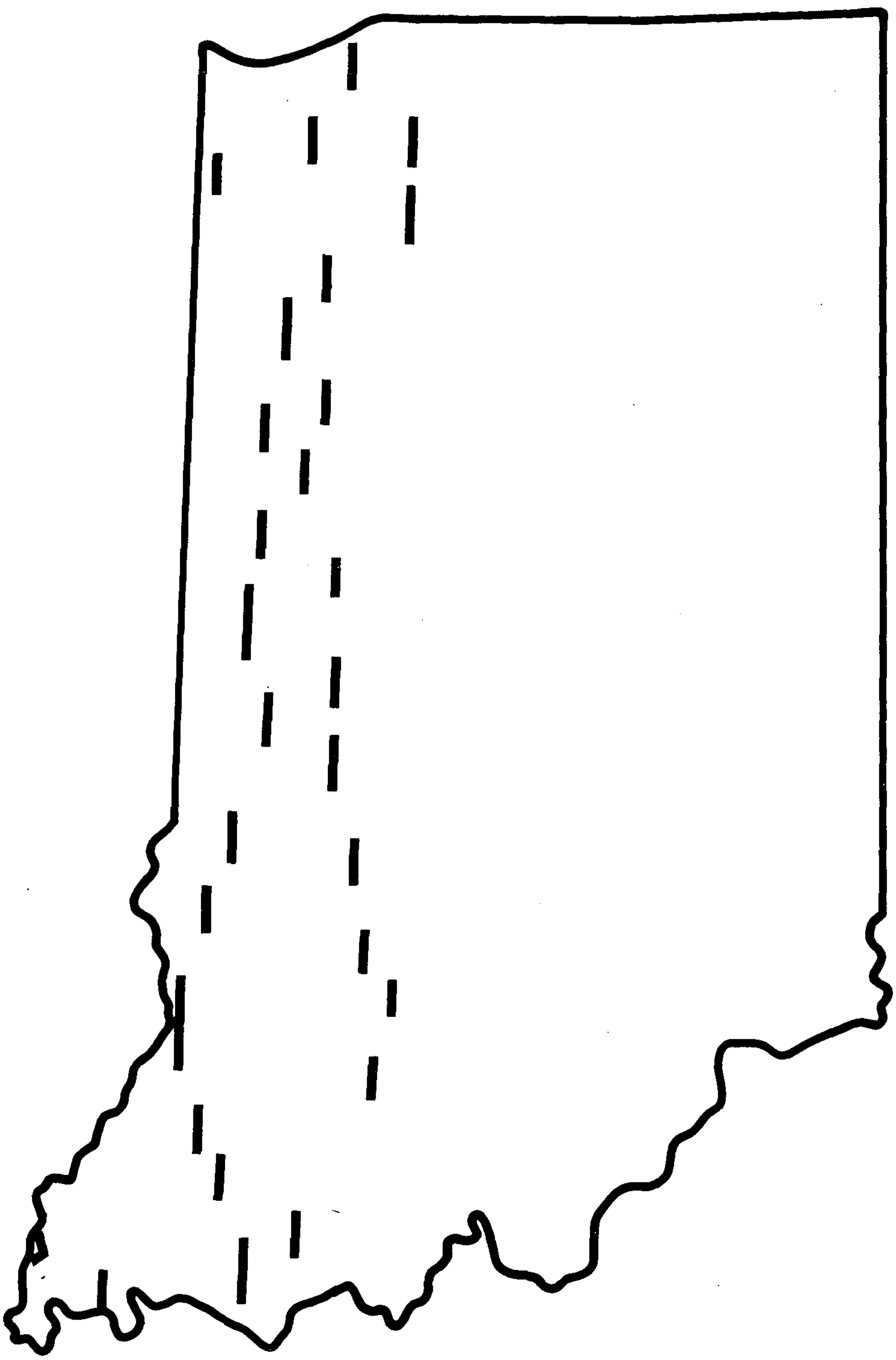


FIGURE 4 - INDIANA INTENSIVE STUDY AREA

N79-29420



SECTION 128

# 1971 CORN BLIGHT WATCH EXPERIMENT DATA PROCESSING, ANALYSIS, AND INTERPRETATION

by

Terry L. Phillips and Staff
Laboratory for Applications of Remote Sensing
Purdue University
Lafayette, Indiana

## INTRODUCTION

The nature of the Corn Blight Watch Experiment and available resources to conduct the experiment dictated that there be several centers of activity supporting the overall objectives. Mr. Robert MacDonald described in an attached paper the experiment overview and participants. Dr. Marvin Bauer described the corn blight problem. In other attached papers Mr. Richard Allen discussed the sampling model and ground data measurements program while Mr. Ronald Blilie presented the aircraft data acquisition for the experiment. In this paper the Corn Blight Watch Experiment will be described from the point of view of data processing, analysis, and interpretation procedures. Data availability will be illustrated by discussing the data flow for the experiment and the data catalog system. Descriptions of the analysis procedures, a storage and retrieval system called the Corn Blight Record, and a capability for results summarization will be presented to show the methods used in obtaining the results discussed in Dr. Christian Johannsen's paper.

Early planning meetings for the experiment resulted in the concept of a central data reduction center where all preprocessing and processing functions would be performed. The data collected would be delivered to this center and a final output would be sent to the USDA Information Center in Washington. The advantage of a central site was that maximum communications between the individuals performing separate reduction functions would occur. Also, the time required for transferring data between data reduction locations would be minimized. The central reduction site concept was considered optimum for achieving the greatest possibility of success for the experiment; however, the resources available to the experiment did not permit its implementation. An alternate plan was conceived and implemented. Centers were identified where resources were made available to perform particular processing functions. A data flow plan which maximized the efficiency of data transfer and minimized the data delivery time was designed.

The princiapl data acquisition centers were: NASA/MSC for the collection of high-altitude photography, Willow Run Laboratories at the University of Michigan for collection of multispectral data, and the ASCS and CES county personnel to serve as ground enumerators. The principal data processing centers were: NASA/MSC for the processing of high altitude film and the identification of frames showing the segments identified in the sampling plan; the Statistical Reporting Service of USDA in Washington, which assumed the responsibility for collecting, editing, and collating all ground observations, drawing inferences from them, and delivering products to the data reduction center at LARS; the Willow Run Laboratories at the University of Michigan, which accepted the responsibility to process 15 flightlines of multispectral data and report the results to the LARS/Purdue Data Reducation Center; and the LARS/Purdue data reduction center, where the other flightlines of multispectral data were to be reduced and the 210 segments of photography were to be interpreted. LARS was also responsible for collating and analyzing all interpreted results and for reporting them to SRS in Washington and to other participants in the experiment.

Since the principal data reduction center was located at LARS/Purdue and most data products were handled at this center, a method of keeping track of data products was required. Therefore, a data storage and retrieval system was established and maintained to aid in accessing the data collected.

The purpose of the system was to:

- Store data products in an organized library.
- Maintain a record of all data stored and reduced for future access.
- Report to the photointerpreters and multispectral data reduction teams all required information in a format that allowed the simplest access possible by the teams.
- Record data reduction results from photographic and multispectral scanner data reduction teams and merge the results with the data collected.
- Report data reduction results to the Statistical Reporting Service in Washington and to other participants in the experiment.

## DATA FLOW

The Corn Blight Watch Experiment was conducted in three phases. The data flow plan is best presented by describing the transfer of data from data acquisition centers to and between the data processing centers for each phase. The data flow plan is graphically shown on diagrams which include each center and each transfer of data between the centers. Each center is shown on the diagrams as a node with an abbreviation for the center. These abbreviations are identified in Table 1.

### Phase 1

During Phase 1, baseline data for the entire Corn Blight Watch Experiment were collected between April 15 and May 15. Data Acquisition for Phase 1 included the collection of black and white photography over each of the 210 sample sites and the interviewing of tract operators by ASCS enumerators. Processing included the reduction of photography to a scale of 1:20,000, the outlining of tracts and fields on the reduced photography, and the reporting of farm operator interviews through SRS to the data reduction center at LARS. Figure 1 shows the data flow for Phase 1.

NASA flew two six-inch focal length cameras at 50,000 feet to obtain two original exposures of 36 flightlines containing the 210 samples sites. The scale of this black and white panchromatic photography was 1:100,000. The segments were located, enlarged to a scale of 1:20,000, and three identical prints of each site were delivered to SRS in Washington. A duplicate set of the original photography was also sent to ASCS. All baseline photography was collected with less than 10% cloud cover present. For some segments not photographed within the time period or cloud cover conditions, existing ASCS photography was used.

At SRS the segment was outlined on one copy of each print and this was sent with initial interview forms to the Agricultural Stabilization and Conservation Service county enumerators. Each farm operation in the segment was outlined and visited by the ASCS enumerator. During the interviews a field ID was assigned to each field, field boundaries and ID annotations were added to the photograph, and the initial interview forms were filled out for each field in the segment. The annotated photographs and completed initial interview forms were delivered to SRS. The annotations were copied onto the other two sets of prints and the data on the forms were coded, punched, edited, and recorded in digital format. One set of baseline photographs and a digital copy of the initial interview data were sent to the Data Reduction Center at LARS/Purdue. A second set of baseline photographs was sent to the Cooperative Extension Service in each state where segments were located.

## Phase 2

In Phase 2, between May 10 and May 30, color IR photography was collected over the 210 segments and multispectral scanner data were collected over the 30 intensive study area segments. This data was analyzed for soils characteristics to provide soils background information for corn fields in the segments. The flow diagram for Phase 2 is shown in Figure 2.

## Phase 3

Eight missions were conducted during Phase 3 between June 14 and October 13, 1971. During this phase, color IR photography was collected every 14 days over all 210 segments and multispectral measurements were collected every 14 days over the 30 segments in the Intensive Study Area. Early in each 14-day period, ground observations of up to 12 corn fields in each segment were acquired. These data were processed and sent to the data reduction center at LARS. Fifteen segments of multispectral data and accompanying ground observations were sent to the data reduction center at WRL. The photographic and multispectral data were analyzed and results recorded by the data storage and retrieval system. The analysis results were reduced and reported to SRS in Washington and to other participants in the Corn Blight Watch Experiment. The major data transfers for Phase 3 are shown in Figure 3.

During Phase 3 a new mission was started every other Monday, June 14, June 28, July 12, July 26, August 9, August 23, September 6, and September 20. Each mission was completed in 21 days and results were punched, checked, collated, and reported 23 days after the mission had began.

Only 14 days were scheduled for the collection of color IR and multispectral data. Data were collected initially over segments when cloud cover was 30% or less. If time and weather permitted, reflights were made when data on initial collection over segments resulted in more than 10% cloud cover. All such repeated flights were made when segments in question were expected to be covered by clouds 10% or less.

As in Phase 2, color IR photography (film type 2443) was collected at a scale of 1:120,000 over 36 flightlines. NASA/MSC identified the frame numbers to be analyzed and indicated the best frames when re-flights were taken. NASA/MSC sent two transparencies and two positive contact prints of all color IR photography to the data reduction center at LARS.

The WRL aircraft collected multispectral data over the 30 segments in the Intensive Study Area. All data over the segments were checked at the data reduction center at LARS and immediately sent to the analysis center for processing.

When required by the analysis teams, low-altitude large-scale photography was collected over a number of segments within the Intensive Study Area. These data were analyzed in conjunction with ground measurements to establish the exact condition of a number of fields. This information was used both to evaluate the performance of interpretation or of machine processed data results and to determine the source of any difficulty in data reduction.

Six to twelve corn fields in each of the 210 segments were designated by SRS to be visited by CES and data forms were distributed to each enumerator. Their biweekly reports were sent to the SRS state offices during the first week of the period, and, for the 30 flightlines in the Intensive Study Area, results were phoned to the Data Reduction Center at LARS and WRL. In each of 24 segments, up to 6 fields were designated to be visited by ASCS enumerators to provide test field information for data reduction results. These reports were also channeled to the SRS state offices where they were edited, coded, and punched onto data cards. At SRS in Washington, they were error checked, copied onto digital data tapes, and listed on ground observation printouts. The biweekly data were delivered to the Data Reduction Center, and Ground Observation Summaries, described later, were distributed to the analysis teams by day 10 of each biweekly period, the same day as photographic data were available.

## Data Catalog

The Data Catalog, a previously existing system at LARS, was used for the Corn Blight Watch Experiment. This data storage and retrieval subsystem includes a method of storing film, analog tapes, and digitized tapes for access by the data reduction teams. The Data Catalog subsystem uses an indexing scheme and computer programs for listing information about the storage location of available data.

Figure 4 shows a block diagram for the Data Catalog subsystem. As the data was received, it was stored in a physical location specifically suited for the storage of particular data types. For example, the baseline photographs were stored in a map file cabinet where they did not have to be folded or otherwise mutilated. The 9x9-inch prints were stored in a file cabinet and the roll film was stored in storage bins specifically constructed for 9-inch rolls and 70-mm rolls of film. The analog tapes were stored in an environment specifically suited for analog tapes as were the digital tapes. At LARS, 15 flightlines recorded on the analog tapes were digitized, reformatted, and stored on digital tapes. The remaining 15 flightlines of analog data were entered into the Data Catalog and sent to the University of Michigan. Each set of data, i.e., analog tape, digital tape and physical roll of film, was assigned a storage bin number for retrieval.

The next step in cataloging data was to record the parameters of each flightline for the non-intensive area and of each segment for the Intensive Study Area on a data catalog form. The information or data index recorded included the date, time, ground heading, equipment, film type, and type of data. This information was punched on computer cards and entered into computer data files. Storage and retrieval software was written to make use of the data files in reporting to the analysis teams what data was available for analysis and its physical location. Two forms of output were implemented. The short form or table of contents included a brief description of all data collected. In most cases this listing was adequate for retrieval due to the familiarity of the analysis groups with the data collected. A reference number included on the short form pointed to a page in the long form Data Catalog. The longer description of data received included most or all of the parameters originally recorded about a flightline or segment of data. This information proved useful to interpreters less familiar with the data.

The importance of the Data Catalog was not apparent during the Corn Blight Watch Experiment, since most data was analyzed immediately upon receipt at the Data Reduction Center. Now that the experiment is over, however, the Data Catalog, the organized method of storing and indexing along with the computer-generated reports, is important in locating data. It should also be noted that with this system an on-line retrieval of the data is possible.

# ANALYSIS PROCEDURES

Each of the data analysis teams was given a Ground Observation Summary for the segments to be analyzed or interpreted. A new summary was distributed each period so that pertinent information required for analysis would always be available. Although the form of the summary, shown in Figure 5, was the same each period, parameters listed were added or dropped from the format according to the needs of analysis teams. In the flight information area of the summary, the segment number, film roll number, frame number, date and time of the flight, and flight direction were listed. Next information for the corn fields visited biweekly was listed as well as some information for all other corn fields and non-corn fields in the segment.

## Photointerpretation

With the film roll transparencies mounted in the Variscan, a rear projection system, the frame indicated by the Ground Observation Summary could be located by a photographic analysis team as shown in Figure 6. Using the summary and the baseline photograph, the biweekly corn fields were located and studied so the teams could train themselves on the appearances of blight levels in the segment. The number of fields used for training varied during the experiment; not all biweekly field information was used.

Next each corn field in the segment was located and interpreted, and the results were recorded on a recording form. These results were coded, punched, edited, and added to the Corn Blight Record for each of the 210 segments. The six teams of photo analysts completed their analysis by day 23 of each period. On the average each segment was analyzed by one week after the data collection date.

## Multispectral Data Analysis

Fifteen segments out of 30 in the Intensive Study Area were analyzed by LARS. The analog tapes were digitized and displayed on a digital display. Figure 7 shows an analyst locating the biweekly fields using a baseline photograph and lightpen. The data from these fields were analyzed using a clustering procedure, and the results were used to determine classes for the analysis and data points for generating class statistics. Next the channel selection program was used to pick four optimum channels for classification at Purdue and 6 optimum channels for classification at WRL. In general all channels of data collected were used during the season. There was no single best set of channels; however, a thermal channel, two reflective IR channels and a visible channel were usually selected for the classification of the segment.

At WRL a similar analysis procedure was followed using analog techniques on the other 15 segments in the Intensive Study Area. Results for all 30 segments were reported both on a total segment basis and on a field-by-field basis with LARS and WRL using the same reporting forms. It should be noted that results on a total segment basis were not obtained by photographic analysis. Instead the entire segment was classified into non-corn and corn classes of different blight levels. This is a more complicated classification than is interpreting blight levels only in corn fields. The multispectral scanner results were also completed by day 23 of the period and were finished on an average of 10 days after the segments had been flown. These results were also recorded on the Corn Blight Record.

## Corn Blight Record

A record of the information obtained for every field in each of the 210 segments has been maintained on digital tape. The system designed for accomplishing this task and implemented for the Corn Blight Watch Experiment is called the Corn Blight Record and is shown in Figure 8. The initial interview data, Form A, and biweekly field observations, Form B, were merged with flight log information, multispectral analysis results, and photointerpretation results. The resulting tapes, one for the seven state area and one for the intensive study area, were the source of most of the listings and tabulations generated during the experiment. We have already discussed the Ground Observations Summary. The Ground Observation Record, which is a sorted listing of all information on the tape, was generated periodically for results analysis.

Data analysis results in the form of remote sensing analysis tabulations were generated on day 23 of each period for SRS in Washington. Expansion of results according to the sampling model for ground observations, photographic analysis, and multispectral data analysis were also generated for each period. Breakdowns of blight results for cytoplasm and for many other parameters were made. Yield calculations and other such studies are now in the process of being made. In addition, the results are now being analyzed using standard statistical techniques such as correlation, analysis of variance, and others.

One last note on the corn blight tapes should be mentioned. The format of the tape and a description of the parameters stored have been documented. The resulting document and a copy of the tape can be made for anyone requiring this data.

### Results Summarization and Dissemination

In Figure 9 the data flow for dissemination of the blight analysis results is summarized. For each biweekly period, color IR photographs were sent to the county enumerators for their particular segments. Questions and training materials were sent with the prints, and results were returned for analysis and evaluation. The purpose of this aspect of the experiment was to acquaint the enumerators with small-scale photography in preparation for future technology.

Summarization of ground observations was performed by SRS within one week of data collection. Photographic and multispectral analysis results were sent to SRS within an average of two weeks after data was collected. These results were available to SRS for compiling blight reports to the USDA information center, which in turn handled press releases to the news media.

## CONCLUSIONS

In conclusion this near-operational test of remote sensing systems rapidly advanced our knowledge of their potential. In addition, it is expected that the data collected will continue to be useful in future research. Data over an agriculturally important area of the country have been collected through a growing season. More than 40,000 fields were included in the initial interview records. Ground observations were obtained for 1,600 corn fields visited biweekly. The results of photointerpretation for 16,000 corn fields were recorded every two weeks, and over 300 square miles of multispectral scanner data were analyzed eight times during the growing season.

The procedures designed for handling the large amounts of data were successful. Where problems were encountered, adjustments were made to insure maximum results, available promptly and in a way that was consistant with the rapidly advancing state-of-the-art.

## ACKNOWLEDGMENT

The 1971 Corn Blight Watch Experiment was planned by representatives of, and supported by, the experiment participants. The procedures summarized herein are a product of the total experimental plan; however, special appreciation goes to Mrs. S. K. Hunt and the Applications Programming group of LARS for their contributions in data management aspects of the experiment. Their work and that of other LARS staff to the experiment was supported by NASA under Grant NGL 15-005-112. References are made to the work of Mr. R. P. Mroczynski with the photointerpretation group, Dr. P. H. Swain with the LARS multispectral analysis teams, and Mr. F. Thompson with the WRL multispectral analysis teams.

Table 1. Principle Center of Data Acquisition and Processing

| | |
|---|---|
| NASA/MSC | - NASA Manned Spacecraft Center, Houston, Texas |
| WRL/U. of Michigan | - Willow Run Laboratories, University of Michigan aircraft system |
| ASCS County | - Agricultural Stabilization and Conservation Service of USDA County Offices |
| SRS/Washington | - Statistical Reporting Service of USDA, Washington, D. C. |
| SRS/State | - Statistical Reporting Service of USDA, State Offices |
| CES/State | - Cooperative Extension Service of the seven states |
| CES/County | - Cooperative Extension Service County Agency |
| DRC/WRL | - Data Reduction Center, Willow Run Laboratories, University of Michigan |
| DRC/LARS | - Data Reduction Center, Laboratory for Applications of Remote Sensing, Purdue University |
| USDA Information Center | - United States Department of Agriculture: Agricultural Information Center Washington, D. C. |

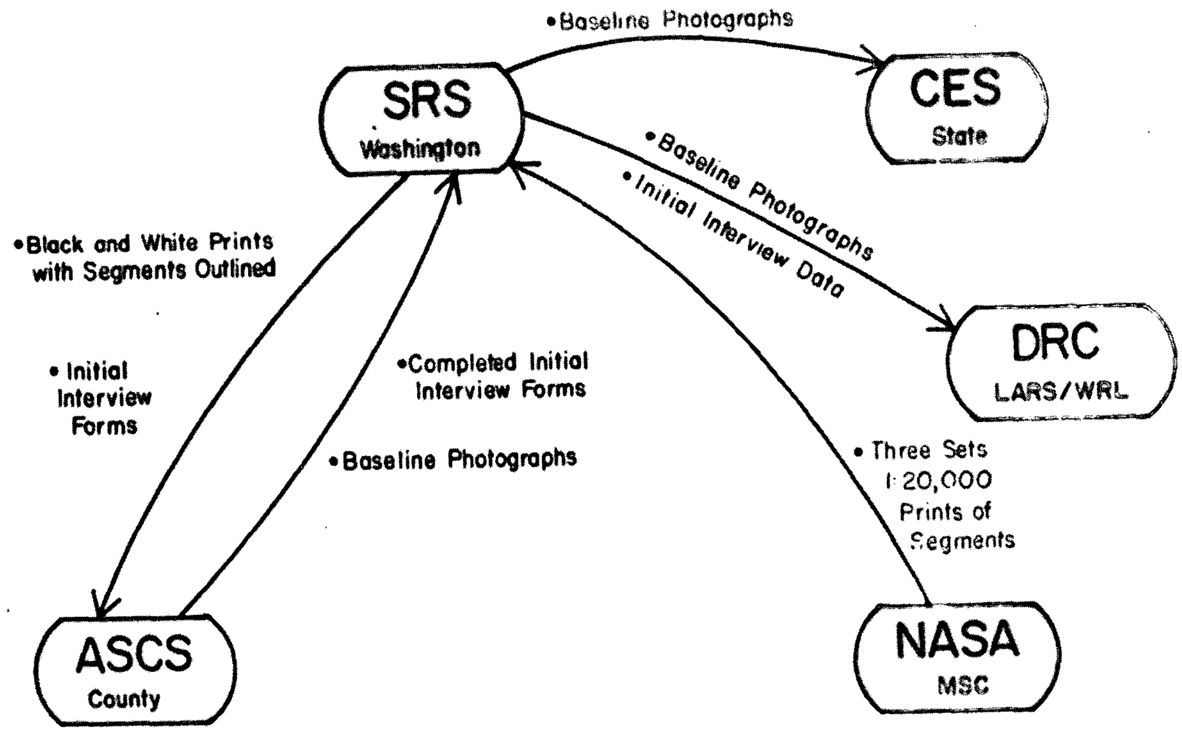



Figure 1. The data flow for obtaining baseline information is designed to provide baseline photographs to the Cooperative Extension Service of each state and baseline photographs and initial interview data to the Data Reduction Center by May 15, 1971. This aspect of the 1971 Corn Blight Watch Experiment was called Phase I, the first of three phases.

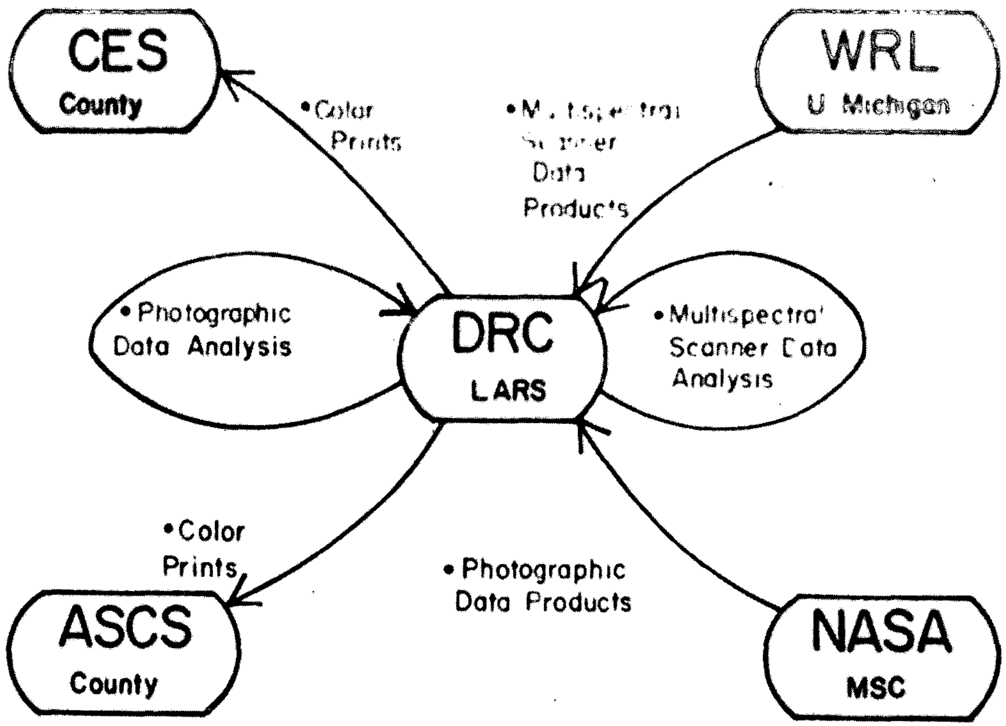



Figure 2. Phase II of three phases for the 1971 Corn Blight Watch Experiment was designed to collect data and perform analysis to determine soils background information for the corn fields. This data flow diagram shows how the objective was completed.

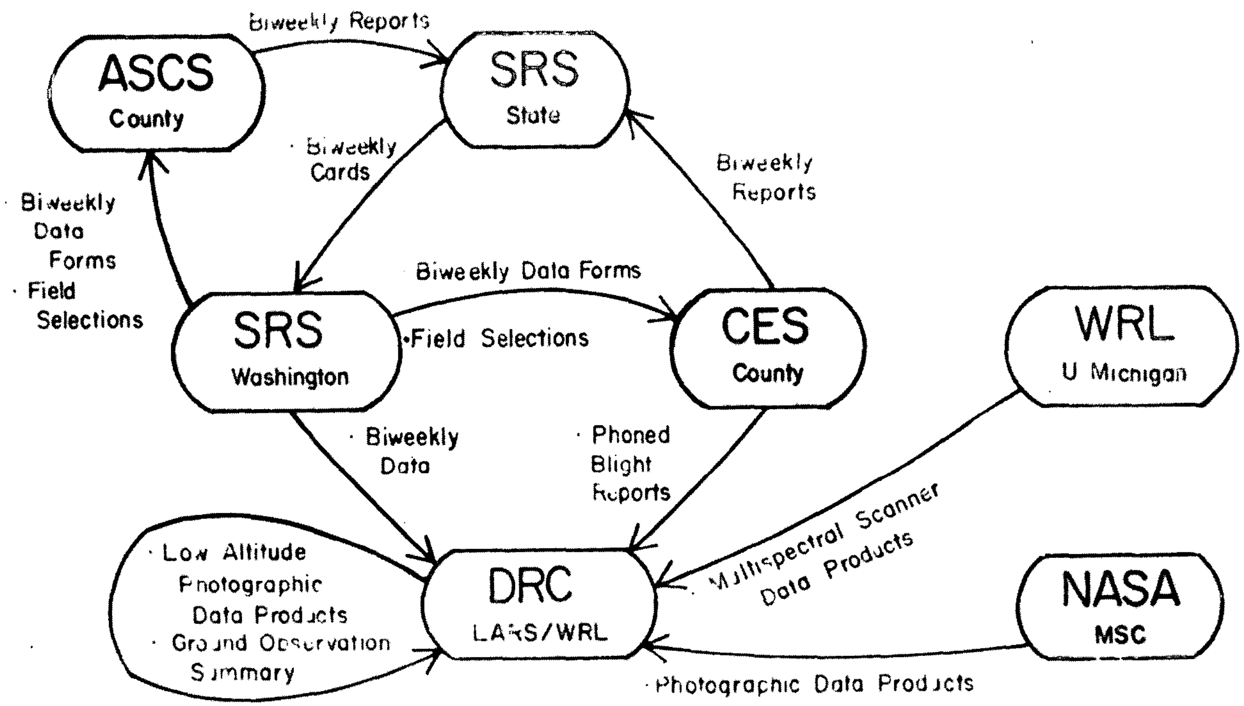



Figure 3. This data flow diagram for the last phase (Phase III) of the 1971 Corn Blight Watch Experiment shows the data acquisition for the experiment. The principal data products are biweekly field data, photographic data, and multispectral scanner data.

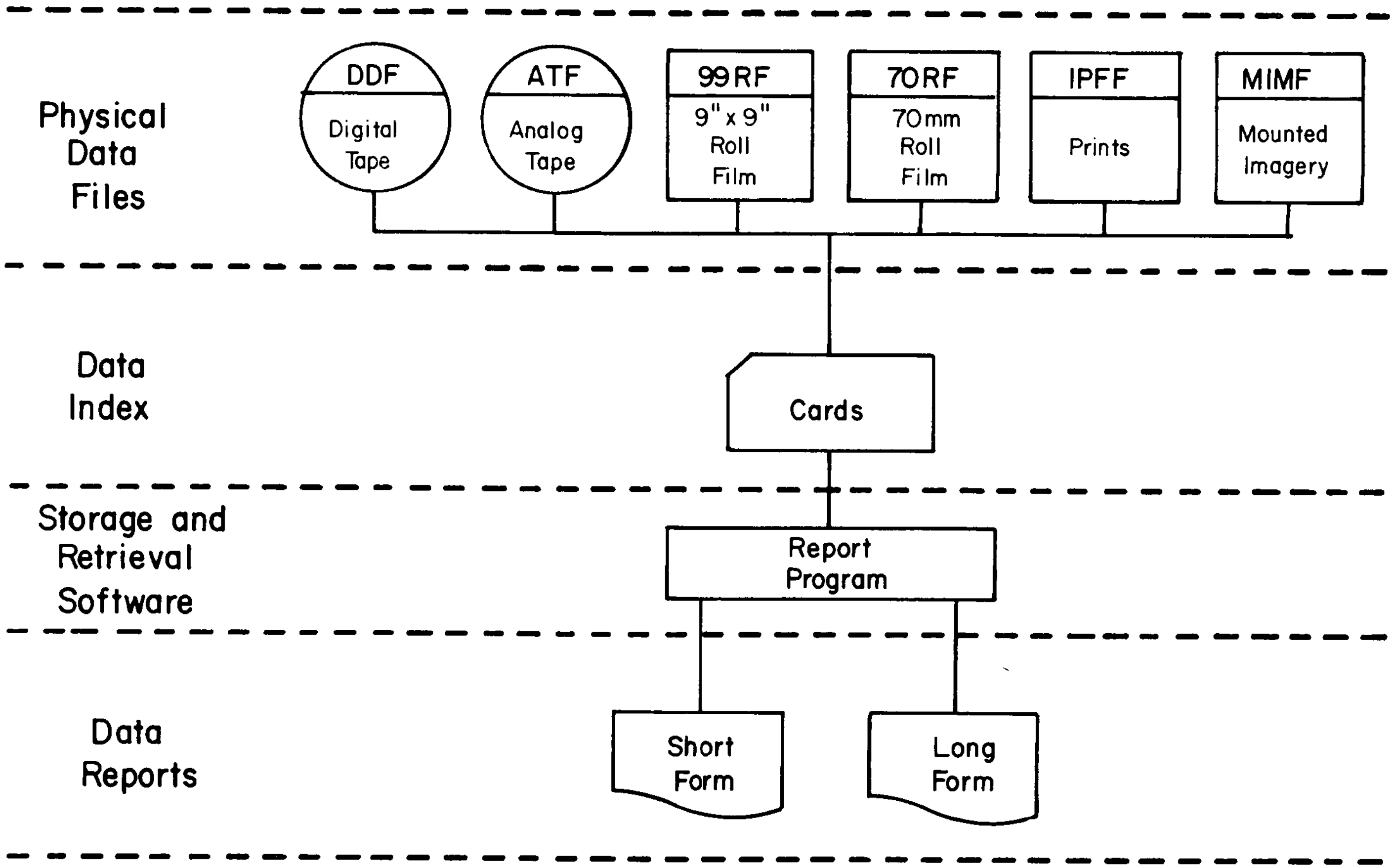



Figure 4. Data for the 1971 Corn Blight Watch Experiment was stored using a data storage and retrieval system called the Data Catalog.

## 1971 Corn Blight Watch Experiment Ground Observation Summary

| |
|---|
| Flight Information |
| Biweekly Corn Field Data |
| Other Corn Field Data |
| Non-Corn Field Data |

Figure 5. The Ground Observation Summary was distributed to analysis teams every two weeks. It contained the flight parameters, new biweekly training field observations (which provided the data foundation in the analysis extrapolation) and basic information of all other fields in the segment.

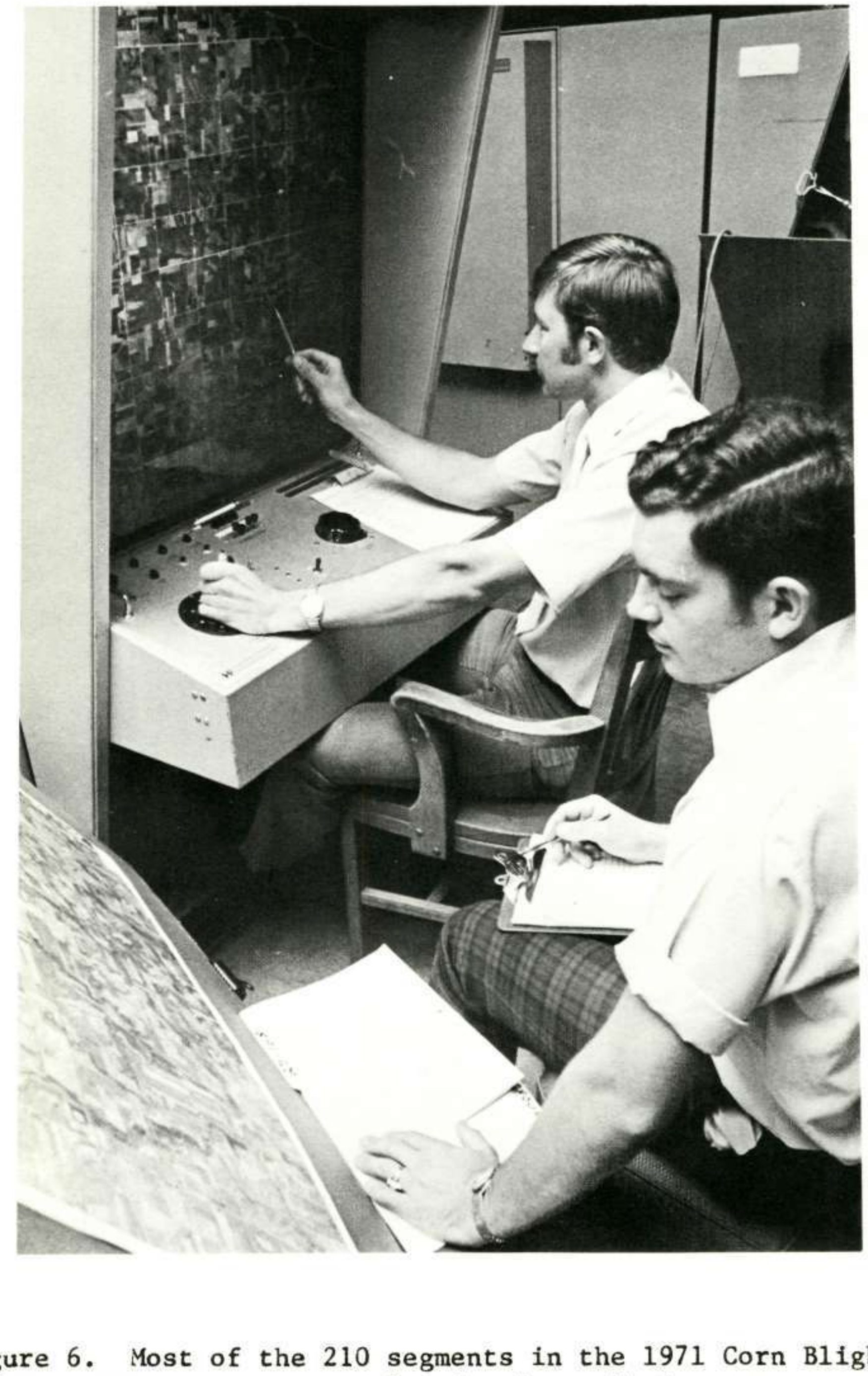


Figure 6. Most of the 210 segments in the 1971 Corn Blight Watch Experiment were analyzed using a Variscan rear-projection system for photointerpretation. Results were reported and rushed every two weeks to Washington.

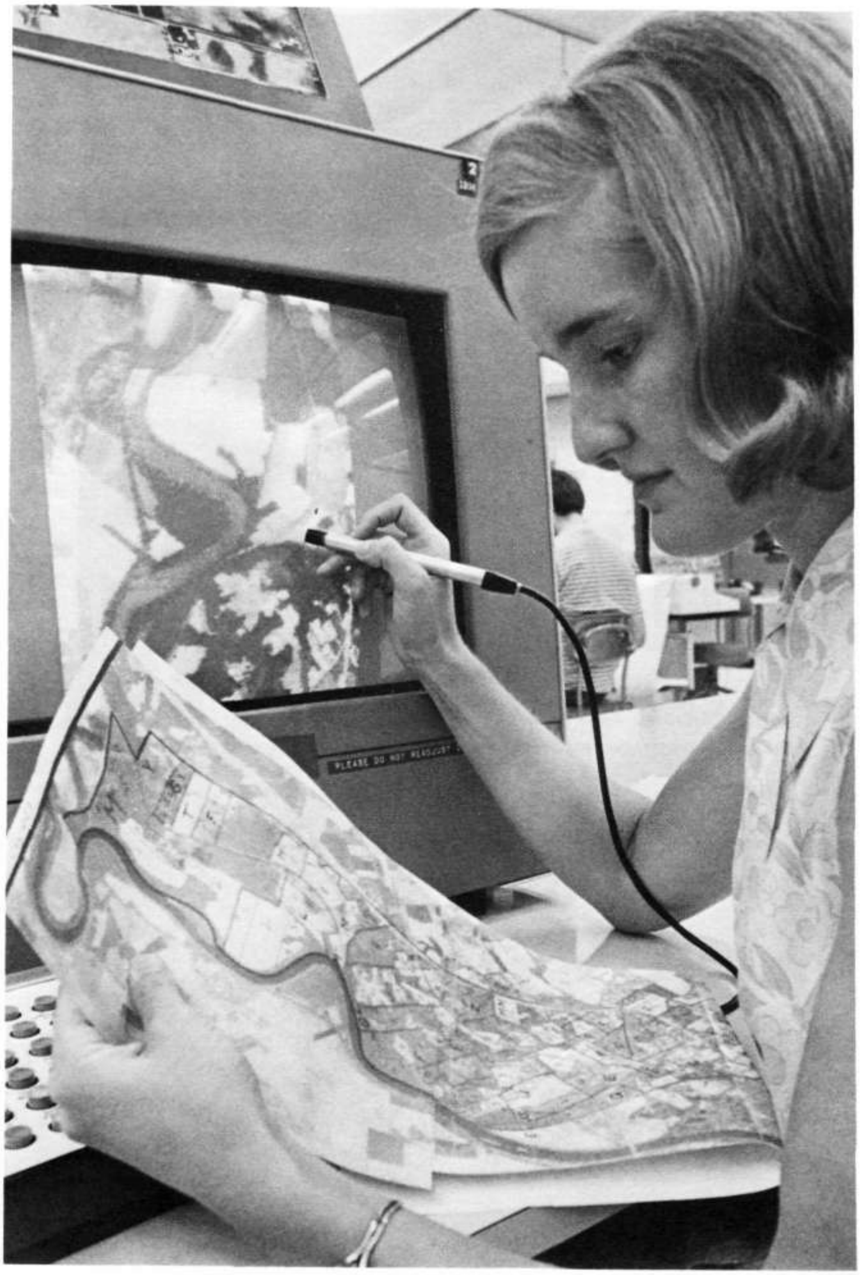


Figure 7. Digital images were used to locate training fields for classification of data from the multispectral scanner. Data from 15 segments were digitally processed and the remaining 15 segments in the Intensive Study Area were processed using analog techniques for the 1971 Corn Blight Watch Experiment.

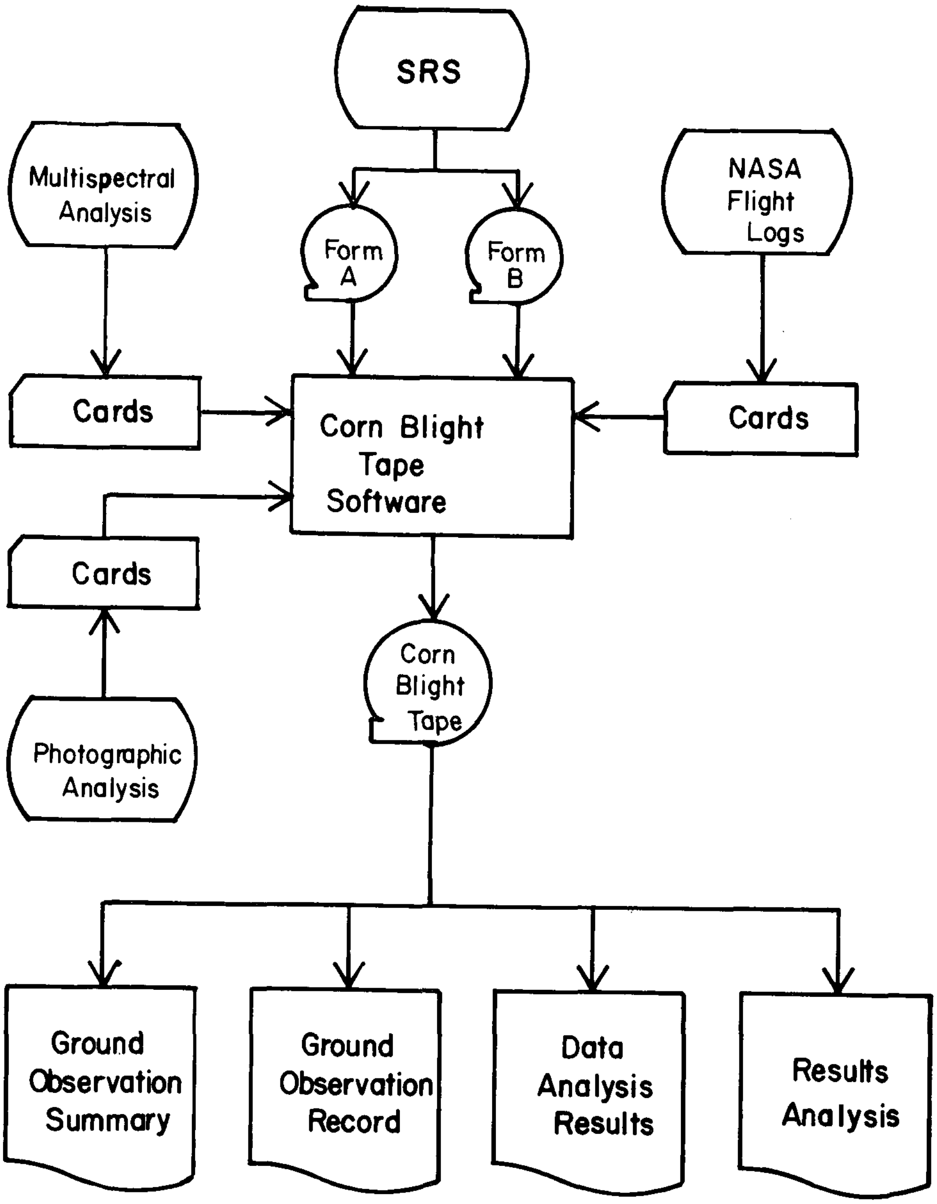



Figure 8. All ground data, flight logs, and analysis results were stored on magnetic tape. These merged data were used to report and analyze results for the 1971 Corn Blight Watch Experiment.

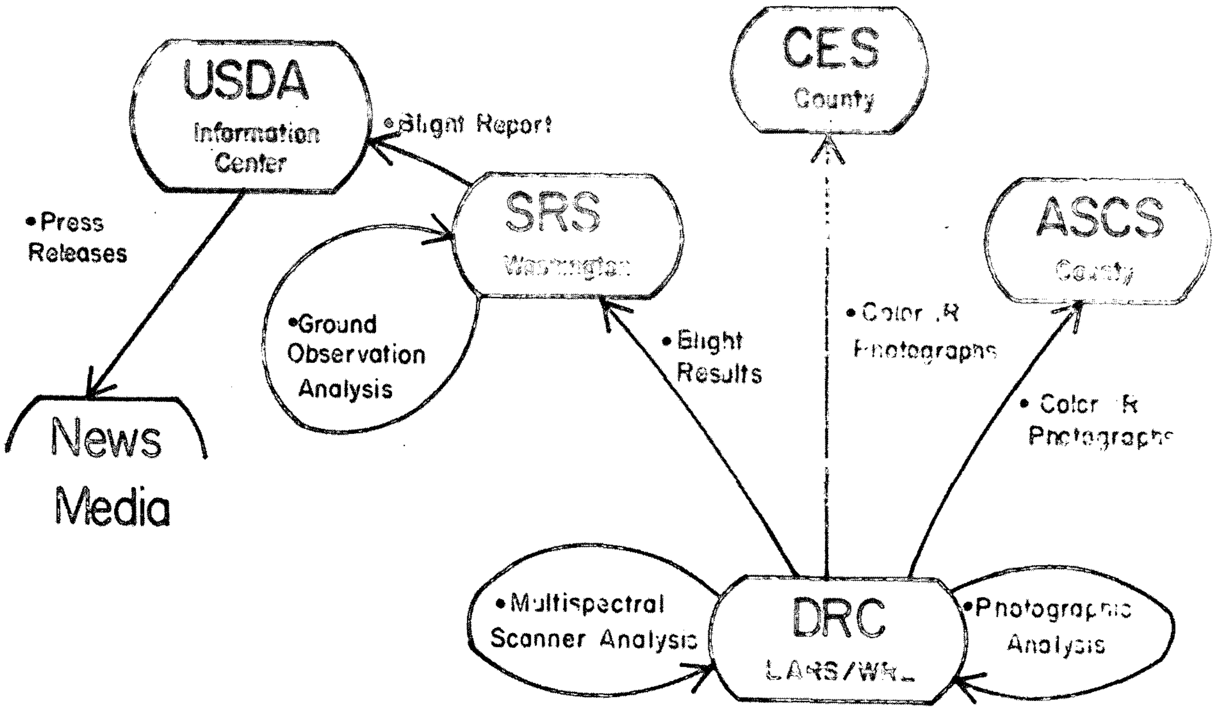



Figure 9. The data flow for results dissemination is diagrammed for Phase III of the Corn Blight Watch Experiment. This last phase of the experiment included the reporting of results to the public.

(PAPER NOT SUBMITTED FOR PUBLICATION)

# SECTION 129

# EXPERIMENT RESULTS GROUND MEASUREMENTS, PHOTO AND MULTISPECTRAL MACHINE ANALYSIS

by Phillip Swain
Purdue University

## ABSTRACT

(Not available)

SECTION 130

# DETAILED INTERPRETATION AND ANALYSIS OF SELECTED CORN BLIGHT WATCH DATA SETS*

by



R. F. Nalepka
J. P. Morgenstern
W. L. Brown
Willow Run Laboratories
The University of Michigan
Ann Arbor, Michigan

## INTRODUCTION

The Willow Run Laboratories of The University of Michigan participated in the Corn Blight Watch Experiment by collecting multispectral scanner data on a biweekly basis over thirty segments in western Indiana and by routinely processing data from fifteen of these segments. In addition to these major efforts, we also undertook a more detailed study of selected multispectral scanner data sets. A brief description of this study and the results achieved therein are the subject of this paper.

A detailed interpretation and analysis of selected corn blight data sets was undertaken in order to better define the present capabilities and limitations of agricultural remote multispectral sensing and automatic processing techniques and to establish the areas of investigation needing further attention in the development of operational survey systems. While the emphasis of this effort was directed toward the detection of various corn blight levels, problems related to the more general task of crop identification were also investigated. The goals of this effort were to: 1) investigate and define improved data preparation and processing techniques and approaches; 2) determine the relative characteristics of crop signatures and their discriminability; and 3) examine the usefulness of signatures on data sets other than those from which they were extracted.

Since the analog recognition computer (SPARC) was fully committed to the more routine aspects of processing and since the detailed interpretation and analysis required more in the way of quantitative information, our CDC 1604 digital computer was employed for this investigation.

* The work reported in this paper was supported by NASA under Contract NAS 9-9784.

Three segments in the intensive study area of Western Indiana over which multispectral scanner data were being gathered on a biweekly basis were selected as potential sites to be included in this investigation. To support this investigation, ground information, in addition to that provided by the county agents, was gathered throughout much of the scanner data collection period. This information included the location of fields, the crop planted therein, as well as the condition of the crop.

## DATA PREPARATION AND PROCESSING

As already mentioned, one of the goals of this study was to investigate and define improved data preparation and processing techniques. The need for such an effort is dictated by information we have gained through our close association with multispectral scanner systems and experiences we have had in processing multispectral data. Our experiences have shown that potentially many problems may exist in each and every data set which, if not corrected, could significantly reduce the accuracy of recognition results for that data. Some of these potential problems are instrument-related while others are associated with the radiation environment and the scene being scanned. These problems include: 1) level shifts and gain changes in the recorded data resulting from instabilities in system electronics and tape speed; 2) misregistration of data between spectral bands due to unequal resolution in all the bands, the lack of optical alignment, either by design or otherwise, of the detectors in all bands, or the imperfect alignment of the tape recorder record and playback heads; 3) noisy data resulting from a combination of insufficient radiation input and lack of detector sensitivity; 4) variations in signal levels as a function of scan angle due to nonuniform angular sensitivity of the scanner, the effects of atmospheric scattering, and bidirectional reflectance effects; and 5) changes in the scene illumination level during the data collection mission.

All of the above problems could seriously affect one's ability to generate accurate classification maps and extract useful information. Without going into much detail here*, we would like to present one of our approaches to the solution of these problems. Prior to digitizing the data, problems of misregistration or skew are eliminated by aligning the data through the use of electrical delay lines. The reference signal used for alignment is one which is recorded in each band during data collection as the scan mirror views a reference source in the scanner. Level shifts are eliminated by clamping the data for each scan line in each band to the dark level signal (that signal which is generated when scanning the dark interior of the scanner housing and which produces zero radiance input to the system).

* More details will be included in the Corn Blight Watch Final Report.

Any gain changes and variations in scene illumination which would produce the same effect as changing the gain are accounted for by scaling the data in each band to the "sun sensor" signal. The sun sensor, which is scanned once for every revolution of the scan mirror, monitors the level of radiation incident upon a flat opal glass plate atop the aircraft. The problems with system noise, as well as those due to misregistration of data in the flight direction, can be significantly alleviated by taking advantage of the fact that in many cases successive scan lines overlap. Rather than not digitizing and processing all scan lines (a common approach), the lines containing largely redundant information are combined by averaging.

All of the above operations can be carried out without specific reference to the video, the data which is generated when scanning the scene. We have chosen to designate such operations as data preparation. One other operation in this category can be carried out. If the angular responsivity of the scanner is nonuniform, and this nonuniformity is known and fixed, the effect of the nonuniformity can be removed from the data. Depending, however, on what other operations are planned for eliminating angle effects, the removal of this effect may be accomplished simultaneously with the removal of the other angle effects. As mentioned earlier, these other effects are due to scattering in the atmosphere and bidirectional reflectance. We have chosen to designate as preprocessing those operations which are meant to reduce or eliminate effects on the data which originate outside the scanner.

One simple form of preprocessing which we have found to be useful assumes that the scene, over its entirety, contains an approximately equal distribution of all objects of interest at all angles. (It is felt that this assumption is valid for most areas devoted to farming.) In this approach, the average signal variation as a function of scan angle is computed for each spectral band. The average signal variation includes the nonuniform angular responsivity of the scanner if it has not already been eliminated.

The effects of scanner angular responsivity, atmospheric transmittance, and bidirectional reflectance are all multiplicative in nature, That is, the radiation incident on an object being viewed at a given angle is multiplied by its reflectance, the transmittance of the atmosphere between the object and the sensor, and the scanner responsivity at that particular angle of view to form the radiation incident on the detector. In the absence of significant path radiance (radiation scattered into the receiver by the atmosphere), which is an additive effect, much of the angular variation in the signal can be eliminated by dividing each scan line of data by the normalized averaged signal variation. Since the data about which we are concerned was gathered under relatively clear atmospheric conditions, path radiance effects would be minimal, thereby justifying this preprocessing approach.

In order to illustrate the importance of properly preparing and preprocessing the data, we now present some examples from data gathered over Segments 203 and 212. The importance of clamping the data to the dark level can be seen in Figure 1 where two histograms, one for the first minute and the other for the second and third minutes of data collection for a particular run, are presented. It is seen here that the dark level varied on the order of ±3% during each of the two periods examined. This variation in itself could seriously affect the ultimate discrimination capability in processing the data. Here, however, an additional shift in the mean dark level of about 5% also occurred during the run.

In Figure 2, examples are shown of the average angular signal variation for two data sets (43M 203 and 43M 212). It is clear on examining the figure that significant variations in the average angular signal occurred for both data sets with more variation present in Segment 203 data. This may be explained by examining the location of the sun during the two data collection flights. For Segment 203 data, the solar elevation was less and the solar azimuth was more easterly than that during the collection of Segment 212 data. With the sun, both lower in the sky and more nearly perpendicular to the north-to-south aircraft flight path, a larger variation of reflectance with scan angle resulted.

A more specific example of the effects of the angular signal variations is shown in Figure 3. Here, we see histograms in two spectral bands of many samples of soybeans and trees plotted as a function of their location in the scene with respect to the data collection aircraft. The effect on both soybeans and trees is a very obvious shift to higher signal value as the scan mirror rotates from east to west. An important result of this shift that is especially noticeable in spectral band 10 is the similarity of signal levels for soybeans on the east and trees on the west side of the aircraft. Obviously, this similarity would create problems in discriminating between and properly classifying both soybeans and trees independent of their location in the scene. These similarities become even more important when it is realized that of the four major object classes in this data set (corn, soybeans, pasture, and trees), soybeans exhibits the highest average signal level in all bands while trees exhibit the lowest average signal levels. Therefore, the signals for both corn and pasture fall between these extremes and one can imagine the confusion that exists between the four object classes and the effect that could be expected on the classification accuracy of the unpreprocessed data set.

The effects of preprocessing the data on the range of signal means for corn are shown in Figure 4. It is seen that a significant reduction in corn signal range was accomplished by preprocessing. Although not illustrated here, similar reductions were achieved for soybeans, pasture, and trees with the result that these crops now exhibited more unique and more easily discriminable signatures.

We have attempted, in the foregoing discussion, to illustrate the importance of careful data preparation and preprocessing in order to permit the extraction of the maximum amount of information from any multispectral scanner data set. Upon further research, the approaches and techniques described may prove not to be the best. Even so, we believe that the application of relatively simple techniques can significantly improve the ability to extract useful information from multispectral scanner data.

## SIGNATURE CHARACTERISTICS AND DISCRIMINABILITY

The second goal of this study was to determine the relative characteristics of crop signatures and their discriminability. While the characteristics of signatures of the various levels of corn blight were of prime importance, the signatures of other major crops and ground covers were also important since they might affect the recognition accuracy of corn.

One of the data sets which was studied and will be reported on here was gathered during Mission 43M over Segment 212. This data set was chosen because it included the first occurrences of high levels of corn blight and fairly complete ground information was available. More manpower was used in gathering ground information at this time since this data set was selected by the personnel of WRL and LARS as a study set to enable a check of the routine recognition processing being carried out at the two facilities.

At the time of data collection (August 17), healthy corn plants were approximately 7' - 8' tall with an estimated ground cover in most corn fields of 90 - 100%. The soybean plants were predominantly 3' - 4' tall with a ground cover of 75 - 90%. Hay fields in the segment were at various stages of maturity, with some having been cut just before the mission. Some fields surveyed early in the year as winter wheat were being used to grow hay or as pastures. Others of the fields had recently been disked. The remaining acreage within the segment consisted of farmsteads, woodlots, and pasture, with a small number of fields planted to oats.

The preparation of this data set for processing and analysis followed the approach described in the previous section. Having prepared and preprocessed the data, the next step was to extract signatures of the various crop and crop-condition classes for analysis. It was decided, for this analysis, to include only fields which appeared to be relatively uniform in the aerial photography and scanner imagery and to further limit the fields to those for which ground information was available. A large number of fields or portions of fields satisfying these criteria were selected.

The signatures from a number of the corn fields were examined using a clustering procedure (this procedure separates data points into groups or clusters and assigns data points exhibiting similar multispectral characteristics to a single cluster). If there was to be any hope of discriminating among levels of blight, the data points from fields of equal blight level should be clustered together. This, however, was not the case. Table I depicts the results of the cluster analysis with the data being assigned to six clusters. There seems to be no correlation between blight level and cluster assignment. However, a weak correlation does exist between the clusters and the location of each field in the segment (east, middle, or west) and the orientation of the rows within each field. As seen in Table I, clusters 5 and 6 include all the selected fields which were located on the East side of the segment, while clusters 3 and 4 include all those fields planted in a North-South direction. These facts seem to suggest that the angle correction applied to the data did not totally eliminate the angle effect present in scanning fields of corn and that this residual effect along with the variable effects of other stresses overshadow any detectable differences in radiation due to levels of corn blight in the range 0 - 3.

In order to check this result, additional analysis of corn blight level signatures were carried out. For this analysis, additional signatures, including some from fields of corn blight levels 4 and 5, were extracted. The mean signal values for each of the signatures (a total of 45) in each of the twelve spectral bands were plotted. Here, too, it was clear that discrimination among levels 0 - 3 would not be possible since the ranges of mean signal values overlapped almost completely in each band. This is illustrated in Figure 5 where the values in five of the spectral bands are depicted. The one somewhat promising indication offered by Figure 5 is the partial separation of blight levels 4 and 5 from levels 0 - 3 in spectral bands 8 and 9. This suggests that levels 0 - 3, 4, and 5 may be separable.

While it is necessary to have unique blight level signatures to insure the ability to discriminate among blight levels, the uniqueness among blight level signatures may not be a sufficient condition for accurate recognition if the signatures of other object classes in the scene are not also distinct. To determine whether distinct signatures existed which would permit the generation of accurate crop recognition maps, signatures were extracted from selected fields of soybeans, pasture, hay, and trees. The ranges of the mean signals in each spectral band for each of these classes was determined. This information along with that for corn is plotted in Figure 6. Upon examining this figure, it is clear that, with the exception of hay and pasture, the signal ranges for every pair of object classes exhibits no overlap in at least one spectral band. The uniqueness of the signal ranges is a good indication that a fairly accurate crop recognition map could be produced if training signatures encompassing the appropriate ranges were utilized.

A crop recognition map, a portion of which is illustrated in Figure 7, was generated. (The field identifications are shown in Figure 8). In the remainder of this section, the signatures used to train the computer and the results of the recognition process are discussed.

As previously mentioned, it was necessary that the training signatures for each object class encompass the range of variability of that class. To satisfy this requirement, a single signature was generated for each class by combining the two individual signatures for that class which fell at the upper and lower extremes of the signal range. The combined signatures, then, had a mean which was the average of the means of the extreme signatures and which included those means within ±1 standard deviation of the combined signature distribution.

Combined training signatures were calculated for corn (blight levels 0 - 3), soybeans, pasture, hay, trees and an object class designated sparse vegetation. The latter class included a wide range of sparseness from bare soil to a fairly high percentage (50%) vegetative cover. In addition to the combined signatures, the signatures from two corn fields were used to train the computer for corn blight levels 4 and 5.

It was decided that the same number of spectral bands (six) would be used in generating this recognition map as were being used in the routine processing of the Corn Blight Watch data. Six spectral bands were selected (2, 6, 8, 9, 10, and 12) which seemed to provide adequate separation between the eight object classes.

An analysis was carried out of the recognition results achieved in identifying corn fields or areas in corn fields containing specific levels of blight. The best that could be said for these results is that they were disappointing. Although most fields which were called out by the observers in the field as exhibiting high levels of blight were recognized as such, many other fields were improperly identified as containing high blight levels. The reasons for the misidentifications were many and varied, ranging from the existence of other plant deficiencies and diseases to one example of a field planted to popcorn which resembled fields containing high levels of blight. A general conclusion regarding this effort is that at this time in the growing season, enough natural variability exists in corn to prevent reliable detection of specific blight levels.

The results achieved in identifying the various object classes in the scene were very much better. The number of acres classified as belonging to each of seven categories are listed in Table II. For soybeans, the number of acres recognized was approximately 85% of the acres planted. The majority of non-soybean classifications in soybean fields were sparse vegetation. In almost all cases, these classifications were judged to be correct since they occurred in regions of the fields where the plants were stunted due to soil drainage problems. Therefore, on a point by point basis, the recognition accuracy for soybeans was actually much better than 85%. In fact, if the recognition results were interpreted on a per field basis, with all fields in which more than 50% of the points were classified as soybeans being considered 100% accurate, the accuracy of recognition exceeds 98%.

The point by point recognition accuracy for corn was significantly lower than that for soybeans. Approximately 60% of the acreage planted to corn was classified as being corn. In this case, too, the largest majority of non-corn classifications were sparse vegetation. Since the corn training signatures were extracted from uniform areas of relatively high ground cover, regions of lower cover would likely not be recognized as corn. If information concerning the likely yield of corn was required, the above approach would be reasonable. However, for a determination of the number of acres planted to corn, it is clear, at this time, that the signatures should have been extracted from areas containing a larger variety of crop conditions.

Of all the corn fields in the segment, 37 were poorly recognized. There was no apparent correlation between soil type, topography, or location of the fields in the segment but the planting density in at least 32 of these fields was lower than most of the corn fields in the segment. This is further indication that signatures should have been extracted from other areas to optimize corn recognition.

The interpretation of the corn recognition results on a per field basis improved the accuracy of a significant amount. Whereas only 60% of the corn acreage was recognized on a point by point basis, 80% was recognized on a per field basis. These results suggest that, in the future, automatic per field classification techniques should be developed.

## SIGNATURE EXTENSION

One of the primary goals of the efforts being undertaken in remote sensing is the development of techniques which will enable large-area crop surveys without the need for expending a significant amount of manpower gathering ground information. If the amount of necessary ground information can be reduced, cost-effective remote crop survey systems will become a reality. To accomplish this goal, the effectiveness of spectral signatures must be extended in time and space.

The discussion which follows describes a relatively successful attempt at applying object class spectral signatures derived from one data set to another set of data gathered on a different day at a different location. In particular, data from Segment 203 of the Intensive Study Area were processed using signatures from Segment 212.

The conditions which prevailed during the two data collection flights are listed in Table III. The position of the sun in the sky, the soil types, the ground moisture, and the visibility were different for the two sets of data. Taken together, the existing conditions were different enough to produce large changes in the magnitude and spectral makeup of the scene radiance. It is changes of this sort that prevent the useful application of signatures over large areas.

The data from Segment 203 were prepared and preprocessed as described in the previous section. The preprocessing included the stabilization of the data by the sun sensor signal and the elimination of angle effects. Since both data sets included a similar distribution of objects having the same basic spectral properties, the differences in the angle-corrected signal levels were used to quantify differences in scene irradiance and atmospheric transmittance at the two locations. This information was then used to adjust the spectral signatures determined from Segment 212 data so that they could be applied to the Segment 203 data set.

As a preliminary test of this approach, the average signal level was determined for each spectral band in the angle-corrected data for both data sets. The ratios of these signals were then computed. It was felt that these ratios could be used to make the adjustment described above. To check whether this would indeed work, signatures were extracted from a limited number of fields in Segment 203. On comparing the means of these signatures to those extracted from similar object classes in Segment 212, it was found that the ratios of the mean signatures for all objects were essentially equal to the ratios of average signal levels in each channel. Based on this limited substantiation of the approach, a recognition map was generated for Segment 203 using the adjusted signatures from Segment 212.

The spectral bands which were used in producing this map were the same as were used in processing Segment 212 (2, 6, 8, 9, 10, and 12). Figure 9 shows the ranges of the mean signals of the various ground cover types in Segment 203 for each of these bands. With the exception of band 9, the choice of spectral bands for Segment 212 appears to be also suitable for Segment 203.

A detailed analysis was made of the recognition results in all the fields in a 2-mile portion of Segment 203. The recognition map for this area is shown in Figure 10. The field identifications for this area are included in Figure 11. Rather than presenting the detailed analysis here, we will indicate the general results achieved in generating this recognition map.

The accuracy of the recognition results for Segment 203 data using signatures from Segment 212 data is somewhat less than that achieved on Segment 212 data. For corn, the detection rate was 45% while the false alarm rate was 10%. These figures for soybeans were a detection rate of 50% and a false alarm rate of 15%.

The hayfields were most poorly recognized. Only 4.6% of the area categorized as hay was correctly recognized as hay. Approximately 77% of the hay area was recognized as pasture or sparse vegetation. The recognition of trees was also not very accurate. These results were not too surprising since the tree recognition accuracy on Segment 212 was not very good. Once again, most of the false alarms were sparse vegetation.

It seems that the signature for sparse vegetation was too broad and that some modification of the signatures would have produced significant improvements in recognition accuracy for both data sets.

Considering the fact that the signals generated when viewing the two scenes were quite different, it is felt that the application of signatures from Segment 212 to recognize objects in Segment 203 was a reasonably successful effort. We believe that these results give reason for optimism regarding the feasibility of operational remote sensing crop survey systems.

RO

TABLE I. -CLUSTER ANALYSIS RESULTS FOR 43M SEGMENT 212

1

| Field | Blight Level | Location in Segment | Row Dir |
|---|---|---|---|
| EE15 | 2 | M | E-W |
| EE9 | 2 | W | E-W |
| EE8 | 3 | W | E-W |

2

| Field | Blight Level | Location in Segment | Row Dir |
|---|---|---|---|
| RR4 | 0 | M | E-W |
| RR3 | 1 | M | E-W |
| UU7 | 1 | M | E-W |
| UU6 | 1 | W | E-W |

3

| Field | Blight Level | Location in Segment | Row Dir |
|---|---|---|---|
| NN2 | 0 | M | E-W |
| UU8 | 1 | M | E-W |
| ZZ7 | 2 | W | E-W |
| *UU1 | 3 | W | N-S |
| N1 | 3 | M | N-S |
| | | | N-S |

4

| Field | Blight Level | Location in Segment | Row Dir |
|---|---|---|---|
| RR5 | 0 | W | N-S |
| UU4 | 1 | W | N-S |
| EE11 | 3 | W | N-S |
| RR2 | 3 | M | N-S |
| UU10 | 3 | M | E-W |
| *UU1 | 3 | W | N-S |

5

| Field | Blight Level | Location in Segment | Row Dir |
|---|---|---|---|
| SSS2 | 0 | E | E-W |
| II1 | 1 | E | E-W |

6

| Field | Blight Level | Location in Segment | Row Dir |
|---|---|---|---|
| SSS1 | 0 | E | E-W |

*Half of this signature clustered in Group 3 and half in Group 4.

TABLE II. -CROP CLASSIFICATION TOTALS FOR 43M SEGMENT 212

| CLASS | ACRES |
|---|---|
| CORN | 979 |
| SOYBEANS | 898 |
| PASTURE | 721 |
| HAY | 291 |
| SPARSE VEGETATION | 2541 |
| TREES | 534 |
| NOT CLASSIFIED | 220 |

TABLE III. -SUMMARY OF CONDITIONS PREVAILING IN TWO STUDY AREAS USED FOR SIGNATURE EXTENSION ANALYSIS

| | Segment 203 | Segment 212 |
|---|---|---|
| Latitude | 41.5°N | 40.0°N |
| Longitude | 87°W | 87°W |
| Date of Flight | 8/13/71 | 8/17/71 |
| Time of Flight | 1053 est | 1120 est |
| Solar Azimuth | 139° | 150° |
| Solar Elevation | 57° | 60° |
| Drainage Conditions | Poor | Good |
| Days Since Last Precipitation | 3 | 7 |
| Amount of Last Precipitation | 1.60 in. | .49 in. |
| Visibility | 9 miles | 13 miles |
| Cloud Cover | < 10% | < 10% |
| Ground Temperature | 74°F | 76°F |
| Relative Humidity | 64% | 48% |
| Dew Point | 61°F | 55°F |
| Flight Direction | N-S | N-S |

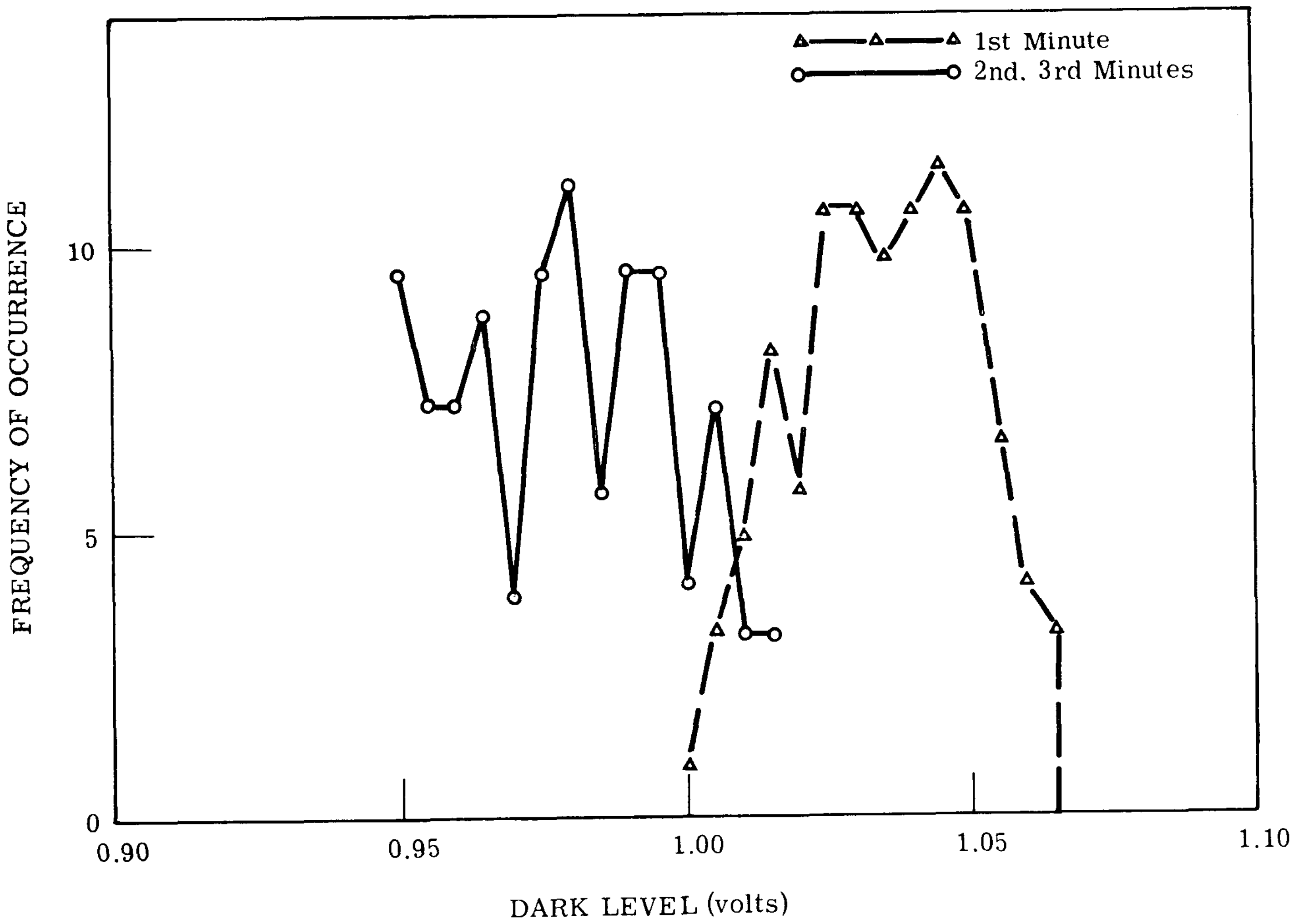
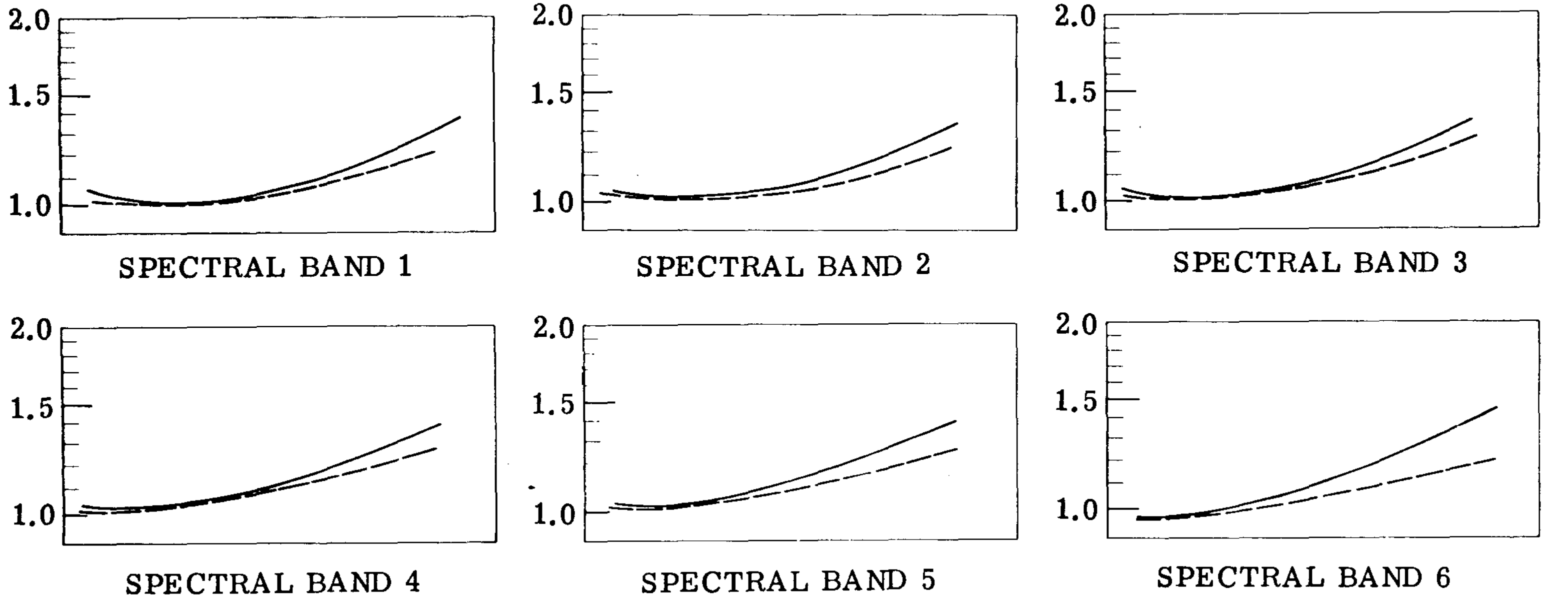


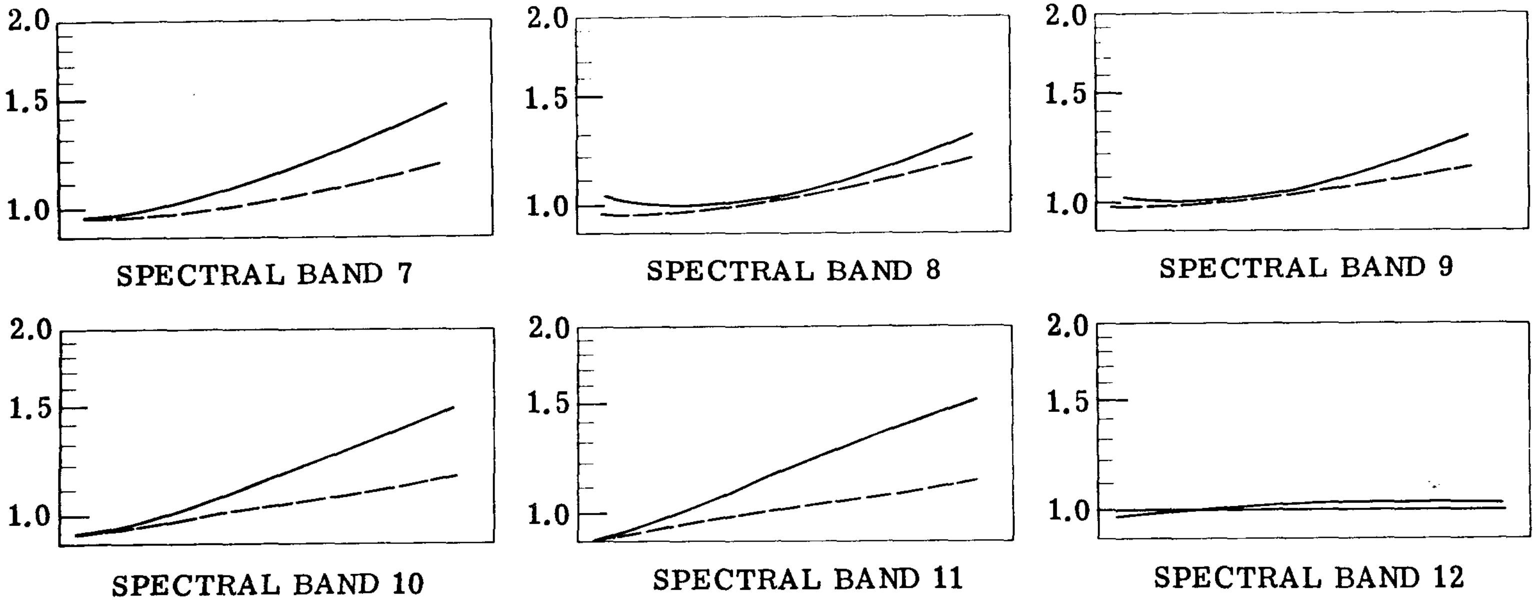

FIGURE 1. DARK LEVEL VARIATIONS IN UNCLAMPED DATA (ANALOG) FOR SEGMENT 203, MISSION 43




Key:

Solid Line: Segment 203
Broken Line: Segment 212

FIGURE 2(a). AVERAGE ANGULAR VARIATION OF SIGNAL FOR MISSION 43




Key:

Solid Line: Segment 203
Broken Line: Segment 212

FIGURE 2(b). AVERAGE ANGULAR VARIATION OF SIGNAL FOR MISSION 43

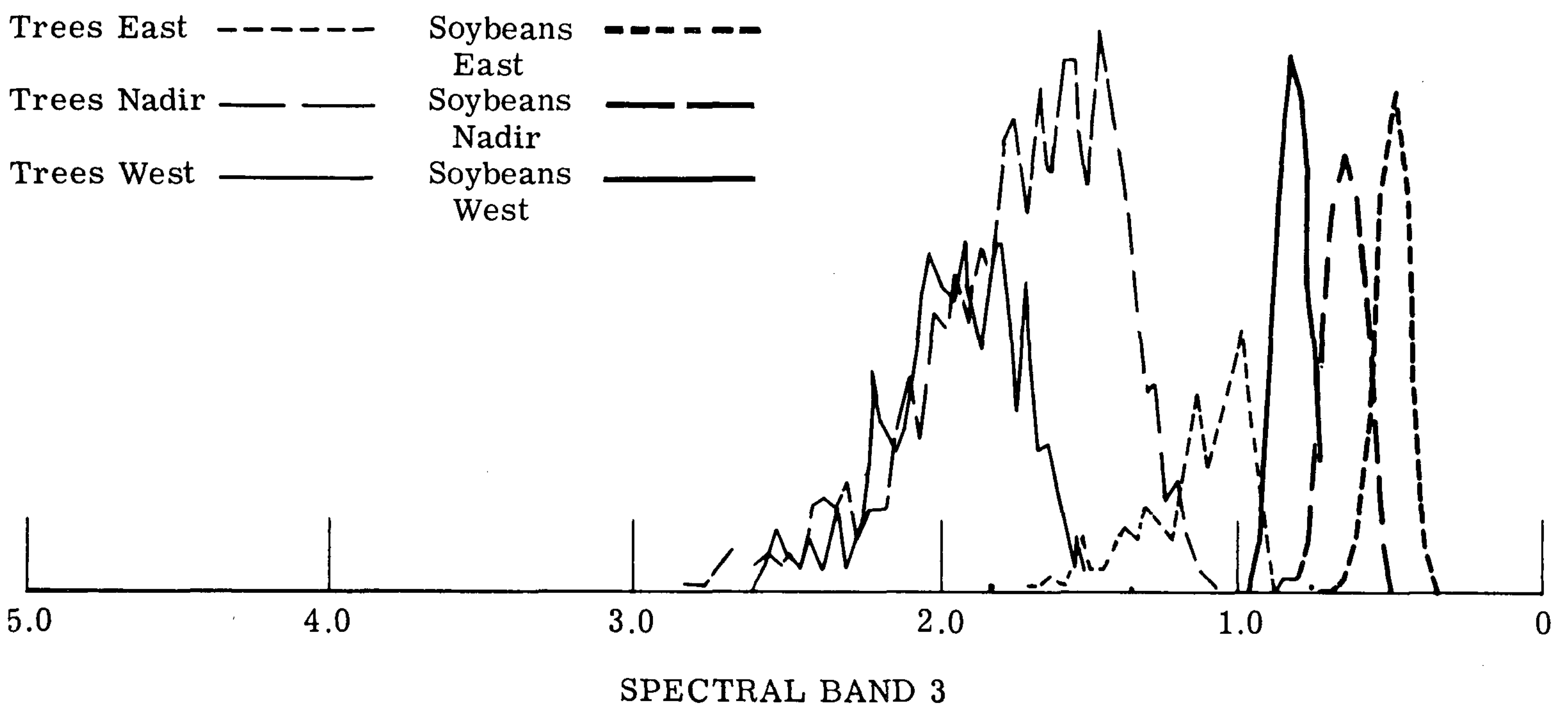



FIGURE 3a. HISTOGRAMS OF SIGNALS FROM SOYBEANS AND TREES AS A FUNCTION OF LOCATION IN SCENE

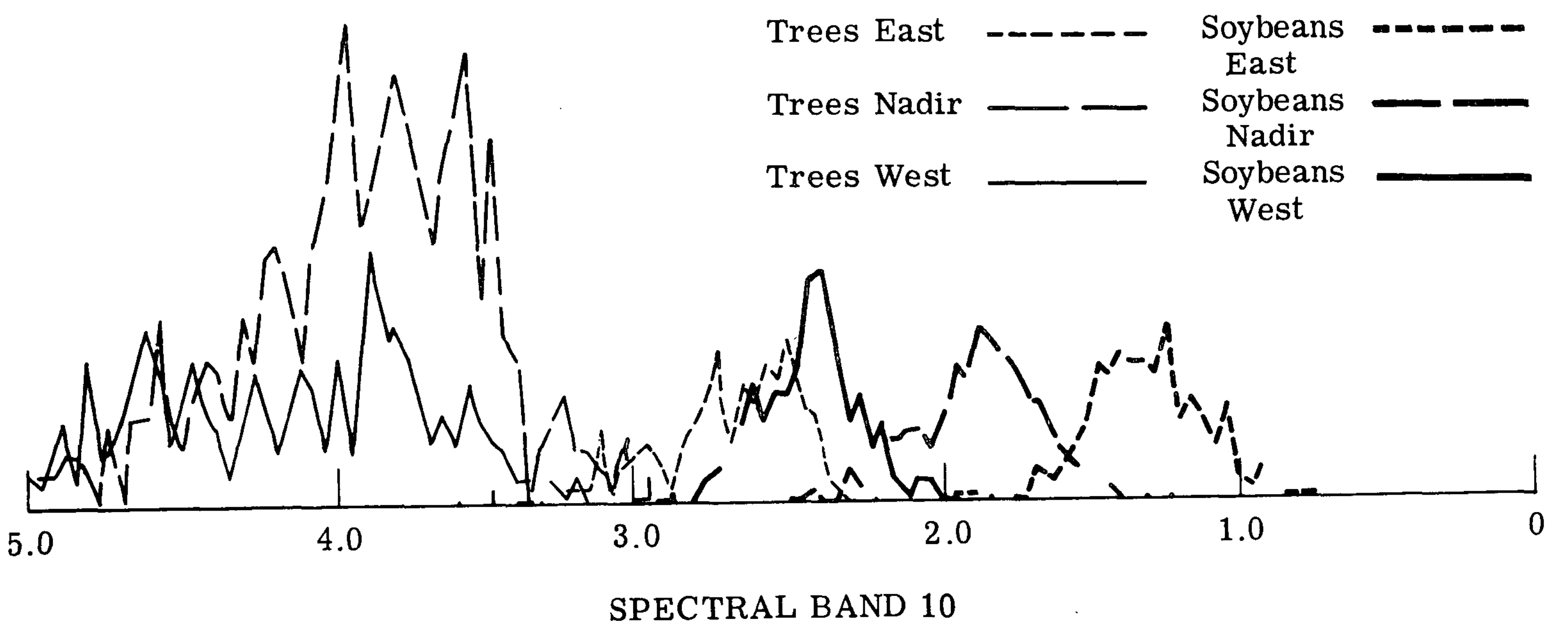



FIGURE 3(b). HISTOGRAMS OF SIGNALS FROM SOYBEANS AND TREES AS A FUNCTION OF LOCATION IN SCENE

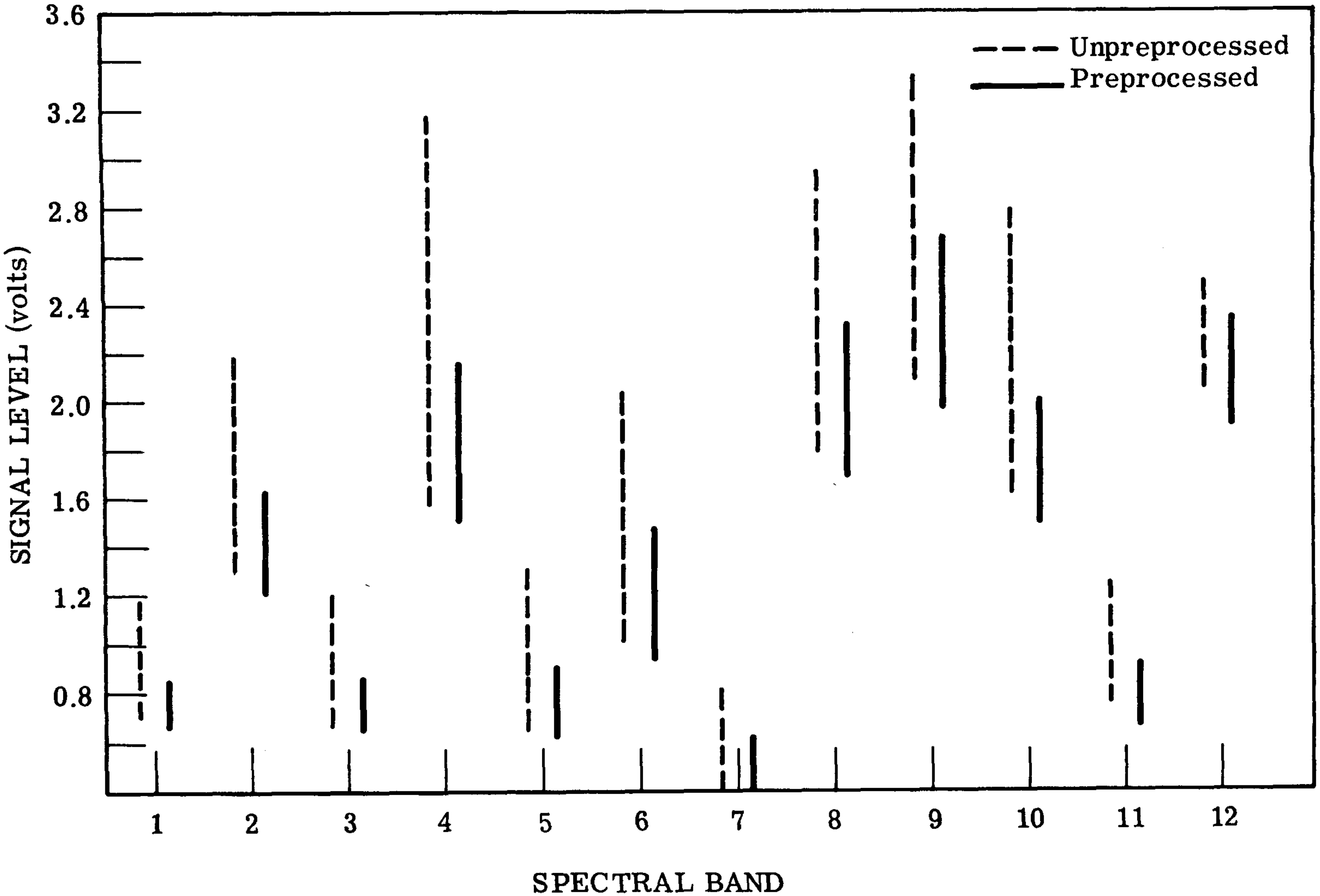



FIGURE 4. RANGE OF SIGNAL MEANS FOR CORN

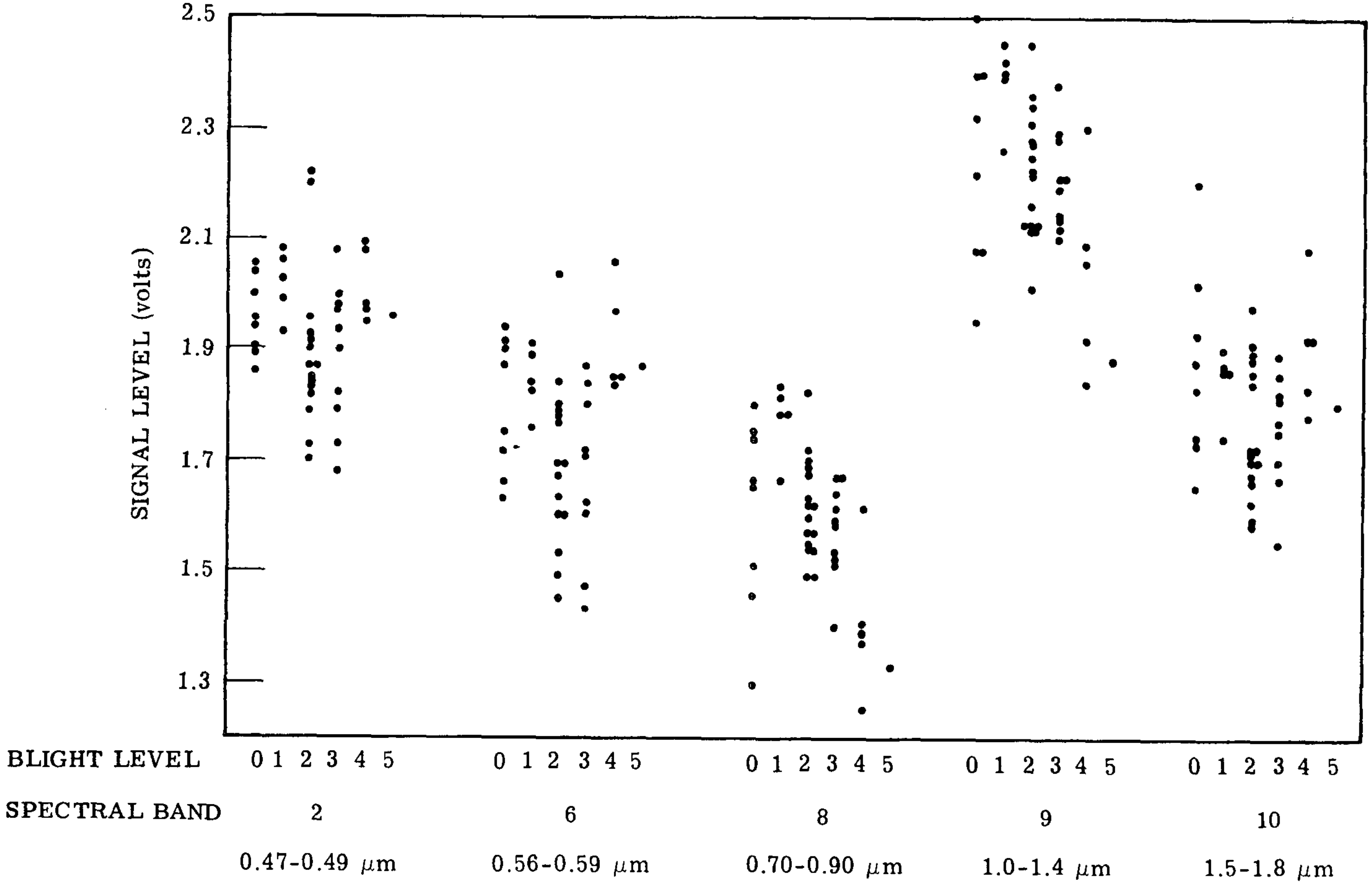



FIGURE 5. VARIATION IN MEAN SIGNALS OF CORN FIELDS FOR SELECTED BANDS BY BLIGHT LEVEL

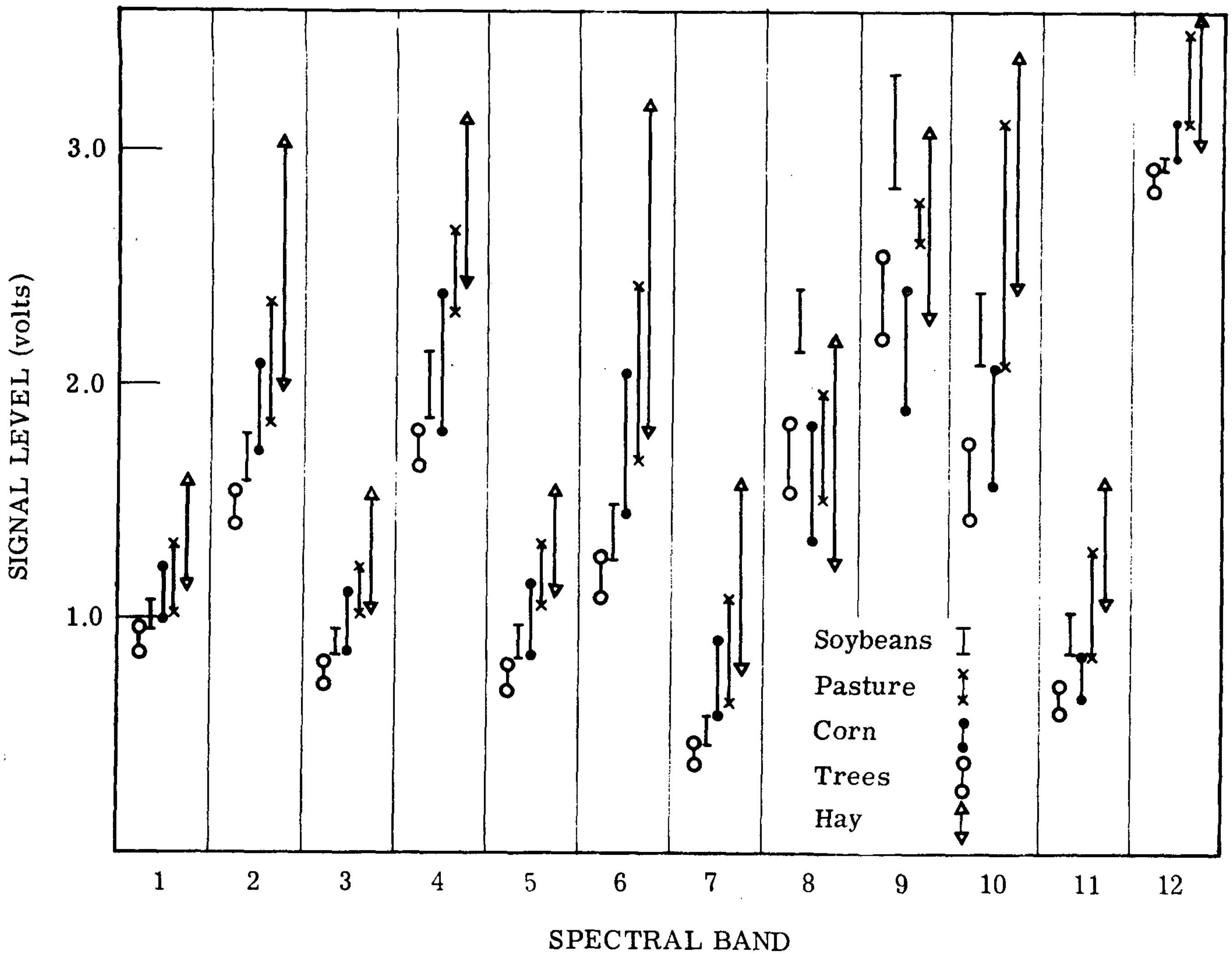



FIGURE 6. SIGNAL RANGE PER CHANNEL FOR 5 OBJECT CLASSES FOR SEGMENT 212, MISSION 43

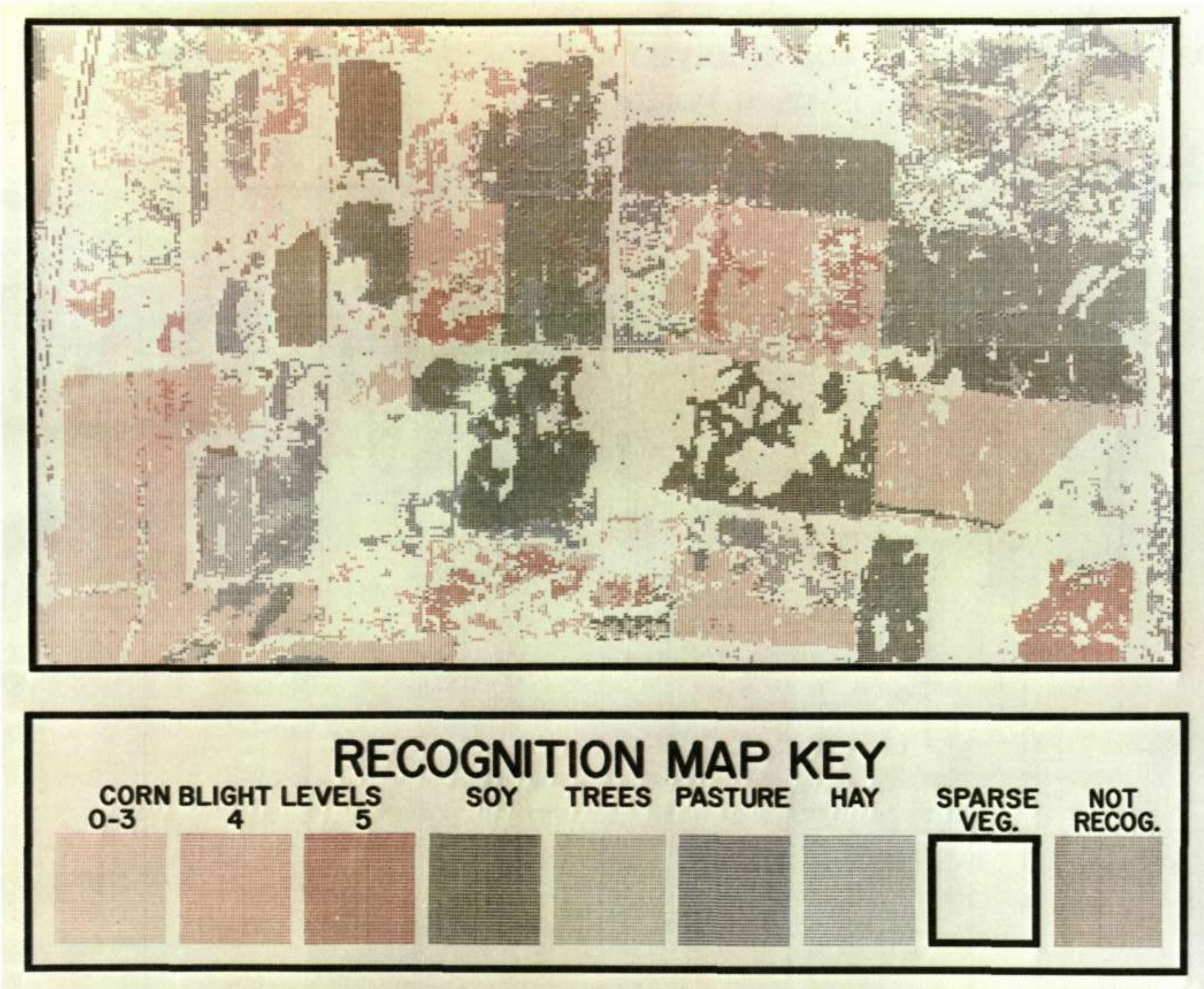
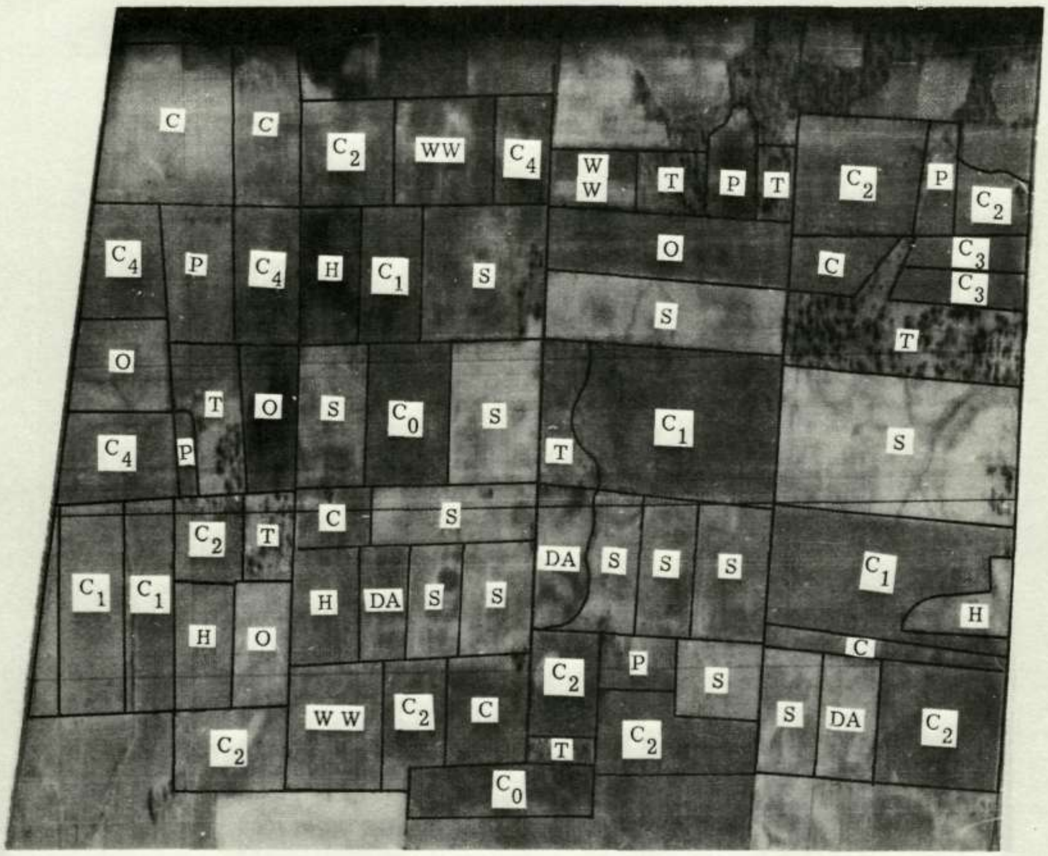



FIGURE 7. DIGITAL RECOGNITION MAP OF A PORTION OF 1971 CORN BLIGHT WATCH SEGMENT 212 (MISSION 43)




Key: $C_n$ = Corn with n the Designated Blight Level
S = Soybeans
WW = Winter Wheat
DA = Diverted Acres
P = Pasture
T = Trees
H = Hay
O = Oats

FIGURE 8. SCANNER IMAGERY OF SPECTRAL BAND 1.0-1.4 $\mu$m FOR SEGMENT 212, MISSION 43. FIELD BOUNDARIES AND COVERS ARE INDICATED.

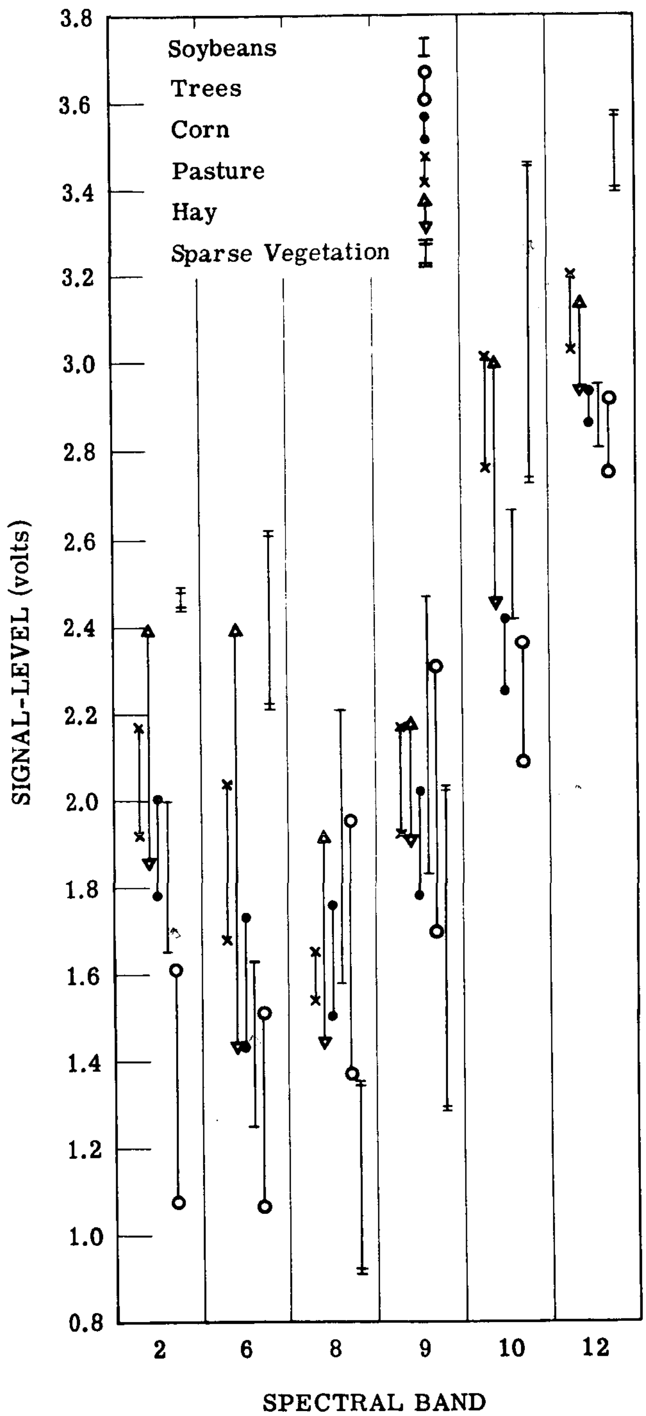



FIGURE 9. RANGE OF MEAN SIGNALS OF GROUND COVER TYPES FOR SELECTED CHANNELS FOR SEGMENT 203, MISSION 43

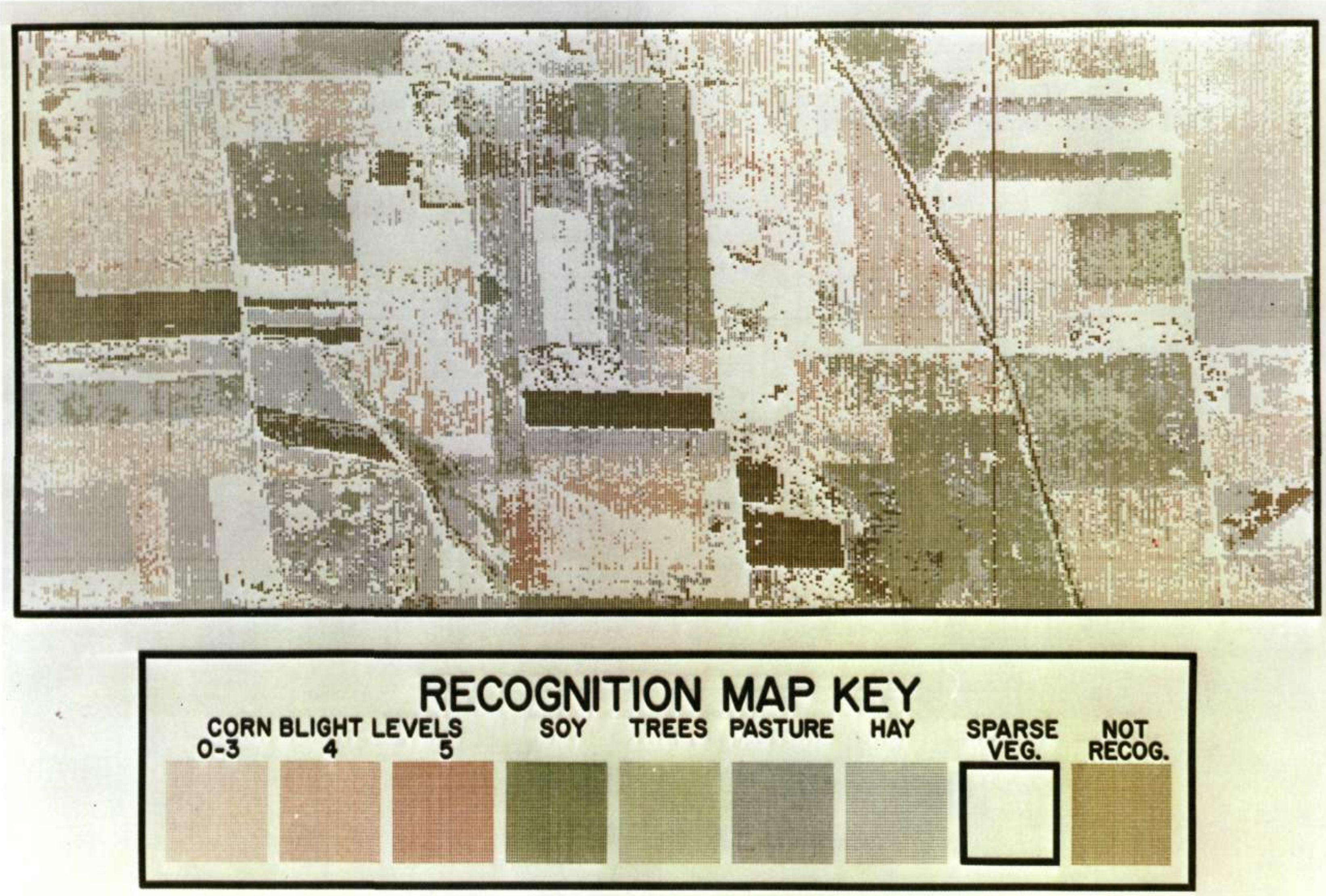
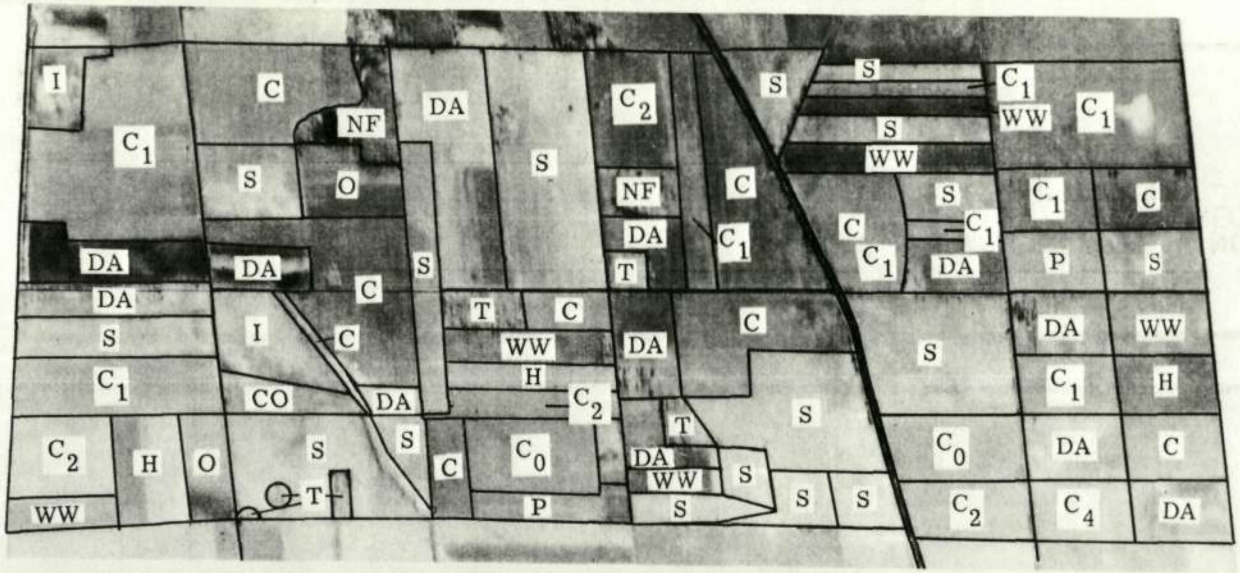



FIGURE 10. DIGITAL RECOGNITION MAP OF A PORTION OF 1971 CORN BLIGHT WATCH SEGMENT 203 (MISSION 43)




Key: $C_n$ = Corn with n the Designated Blight Level
S = Soybeans
WW = Winter Wheat
DA = Diverted Acres
P = Pasture
T = Trees
H = Hay
I = Idle
O = Oats
NF = Non Farm

FIGURE 11. SCANNER IMAGERY OF SPECTRAL BAND 1.0-1.4 $\mu$m FOR SEGMENT 203, MISSION 43. FIELD BOUNDARIES AND COVERS ARE INDICATED.

N72-29422



SECTION 131

# FOURTH ANNUAL EARTH RESOURCES PROGRAM REVIEW OF NASA/MSC

# 1971 CORN BLIGHT WATCH EXPERIMENT

by

J. W. Clifton
Associate Director
Program Performance Division
ASCS
United States Department of Agriculture

This afternoon I would first like to draw a conclusion in connection with the Corn Blight Watch Experiment. The Experiment was successful. To support this conclusion, I would like to examine with you the objectives of the program and evaluate the accomplishments against these objectives.

## OBJECTIVE NO. 1

Detect the development and spread of corn blight during the growing season across the Corn Belt.

Accomplishments to be evaluated against this objective, are:

1. Corn blight was detected early in August using remote sensing techniques. This was accomplished with both machine processing and photo interpreters.

2. Blight was detected and reported earlier in the season by field enumerators, and

3. Data sufficiently valid to locate and trace blight in the Corn Belt was available, but activity was limited because of market sensitivity and lack of resources.

## OBJECTIVE NO. 2

Assess different levels of infection presented in the Corn Belt.

Accomplishments to be evaluated against this objective are:

1. Blight was discriminated with a good degree of validity when infection was moderate to severe by our standards. It was difficult to discriminate healthy corn from mildly infected corn.

2. I feel comfortable about discriminating severely infected corn from mature corn.

3. There is some indication that further research may prove that under comparable circumstances and given the benefit of last year's experience, earlier detection of blight by remote sensing techniques may be possible. We learned that many factors such as the type of soil and nutrients, drouth, drowned-out areas, row direction, other diseases, etc., made this an extremely difficult problem. On the other hand, there is a rather strong indication that blight occurs rather uniformly throughout a field and that consequently, as you zero in on the total field response to the exclusion to these noise factors, the probability of accurate identification is substantially increased.

## OBJECTIVE NO. 3

Amplify information acquired by ground visits to better appraise current blight status and the probable impact on crop production by blight.

The evaluation factors are:

1. Correlation between ground data obtained by enumerators in the field and remote sensing data was good during stages when infection was best identified by remote sensing techniques.

2. Notwithstanding the fact that it was necessary to compromise the statistical model for flight efficiency, the data can be amplified with a reasonable degree of accuracy with respect to the Corn Belt. The total potential in this area was not fully exploited due to the lack of resources and the sensitive nature of the data.

## OBJECTIVE NO. 4

Estimate through extrapolation the applicability of these techniques to similar situations occurring in the future.

Evaluation indicates that the techniques applied to this situation can be adapted to other comparable situations with a high degree of confidence.

These are the factors that support the conclusion that the Corn Blight Watch Experiment was a successful effort--but this is not all--there are other pluses that resulted from the Experiment that I would like to call to your attention:

1. It was a first in organization and management. Never before have so many and diverse elements been blended into a viable working unit--it can be done again whenever the need arises.

2. Research was forced into a "real world" situation, and in my opinion, profited because of it. I would like to emphasize at this point that for research to be most helpful to the operating elements, it is essential that the design of research projects be oriented to the solution of operating problems.

3. Gratifying progress was made in the identification of corn and other crops, although this was not a primary objective of the program.

4. There is substantial evidence that leads us to conclude that not only can corn be identified, but that varieties of corn (resistant and nonresistant) within the same field can be discriminated.

5. The experiment provided the foundation for follow-on developmental efforts in the inventory of earth resources and identified constraints appropriate to such efforts.

6. Some hard lessons were learned on how to handle large volumes of data on a near real-time basis--this experience should help us all in handling the monstrous volume of data that lies ahead for all of us.

In conclusion then, the project rates an unqualified "successful venture" in my book--it was worth every dollar and every drop of sweat from the overworked brows.

I would now like to deal briefly with a misconception that has disturbed some people. The fact that farmers produced some 5 1/2 billion bushels of corn in 1971 should in no way detract from the validity or success of the Corn Blight Experiment. Let me make a couple of real clear statements in that connection. First of all, it was an experiment, and Dr. Bauer earlier explained to you why the corn production for the past year was high.

We did not attempt to design this Experiment to influence the production of corn, nor did we feel that we could control the southern corn leaf blight if and when we found it.

We did, however, design the effort to find out if remote sensing techniques could provide farmers and management with current data that would help them make decisions and whether these techniques could be adapted to other situations.

We did not expect the Experiment to, in any way, financially impact the domestic economy in 1971. I trust this clarifies our objectives and puts to rest some misconceptions about the effort.

Now I would like to take this opportunity, speaking on behalf of USDA, to express our sincere appreciation for the total commitment of all parties involved in the effort--without the dollars, the bodies, and the commitment, this would have been just another exercise. As it turned out, it was in my opinion, another "Giant Step for Mankind" for which NASA is already famous. This effort will, I believe, go into the record books as one of the turning points in the evolution of the Earth Observations Program. It certainly was the basis for initiating the on-going USDA/NASA discussions to further pursue those developments of the Corn Blight Watch Experiment that appear to be promising. We in ASCS, and I feel confident in saying in the USDA, believe there is a great deal of promise in the technology developed by NASA and the Centers of Excellence, and plan to utilize and extend this know-how to the solution of Agriculture-Forestry problems. It is our view that it is in our (USDA) field of effort that remote sensing has its most promising future.

Thank you for inviting me to participate with you in this Fourth Annual Earth Observation Program Review--it has been a most enjoyable and pleasant experience.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1972—770-624